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Optimization of the Structure of the Investment Portfolio of High-Tech Companies Based on the Minimax Criterion

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Abstract: A model has been developed for the optimization of the share structure of an investment portfolio in high-tech projects supported by the leaders of the leading industry companies in Russia. Several indicators (financial leverage, integrated rating of companies, industry rating) were applied in the decision support system for the shared distribution of investments. High-tech production is based on innovative technologies for saving resources, the resiliency of systems for transporting and transferring raw materials and finished products within Russia, so the main income will remain within the country. It is possible to export high-tech products, rather than raw materials, which will increase export revenues. Investors will invest in high-tech projects of Russian companies, taking into account the targeting of investment development. The guarantee is the stable financial position of the companies and the competitiveness rating. Methods: The authors propose a new approach that does not contradict modern rating scales, based on a hierarchical rating procedure and fuzzy logical rules that allow you to build an integral rating in the form of portfolio shares from the whole. A higher share shows an indicator of the higher investment attractiveness of companies. The industry rating is obtained based on the principle of the company's first affiliation to the highest rating indicator. The final minimax portfolio is based on the initial ratings in a circular convolution and is then adjusted by industry. A software package has been compiled that allows the testing of the method of capital allocation between investment projects for the largest companies' leaders of high-tech industries in Russia. This software uses the author's method of multi-stage analysis, the evaluation of financial coefficients, the integral ranking and the correction of the solution taking into account the industry attributes. Results: The results are presented with computer-aided design (CAD) in the form of an algorithmized decision support system (DSS). The CAD system is based on a hierarchical algorithm, based on the use of a multi-level redistribution of investment shares of high-tech companies, taking into account the adaptation to the requirements of the return on investment portfolio. When compiling the portfolio, the minimax optimality criterion is applied, which allows the stabilization of the risk by purposefully redistributing funds between the companies involved in the analysis. The authors of the article have compiled an algorithm for the software implementation of the model. Features of the rating approach: the use of the author's mathematical apparatus, which includes a hierarchical analysis of the ranked indicators of the financial and economic activity of companies, taking into account their priority, and the use of a minimax approach to obtain a rating assessment of companies, taking into account the industry attributes. Development: The proposed approach should be used for targeted financing of large industry companies engaged in the implementation of high-tech projects.

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1. Introduction

The development of high-tech production requires making quick and high-quality decisions on the share structure of investment capital directed to support innovative projects of high-tech industries in Russia [1,2] and other countries [3–7]. The investor is focused on profit; it is the high profit of new projects that can attract him, if he is a competent specialist and understands that you need to expect stable, not ultra-high returns [8,9]. The portfolio approach is the most correct, but uses traditional models of portfolio investment. For example, in the classical problem of Markovitz [10], a number of problems arise, since it is necessary to determine the covariance matrix of asset returns, which is not possible in real time. Obtaining approximate data based on the analysis of financial performance over several years significantly slows down the decision-making process and, in addition, leads to a distortion of the optimization result. Therefore, the current direction of research is to improve the technology of portfolio investment of high-tech projects using rating estimates and parameters of the minimax model.

At the same time, there is the question of obtaining the qualitative parameters of the model task, according to which the formation of the portfolio will be performed optimally and will remain stable for a long time, according to the current investment activity (several months or more).

The authors propose a systematic approach that includes the formation of a portfolio based on important financial indicators (financial leverage, profitability, etc.), on the one hand, and company ratings (linear ranks) on the other hand. To select the leading companies, the author's approach of the circular convolution of financial indicators into an index is used. Two problems are solved on the basis of the minimax criterion. As a result, the correction of the portfolio obtained by the minimum risk problem (financial leverage) is performed on the basis of using the solution of the problem with a circular convolution rating. The investor will receive a balanced system of valuation indicators for his portfolio, which is resistant to noise effects and market news. In principle, it is advisable to revise the model after receiving new data on the financial statements of companies included in the investment portfolio (quarterly report, annual report), depending on the depth of the analytical procedure.

The purpose of the study is to develop a CAD system that contains a methodology and algorithm for optimizing the structure of the investment portfolio of high-tech companies based on the minimax criterion.

The tasks of the work are to obtain a CAD structure for high-tech industries (oil and gas), to obtain a conclusion about the financial condition of companies to be analyzed based on the assessment of capital structure (financial leverage), to obtain an integral rating according to the criteria of volume, dynamics and net profit, to obtain the results of solving two minimax problems and to use the solution of the rating problem as a correction of the solution of the problem of minimizing financial leverage (the ratio of debt capital to equity) in the portfolio, to perform program implementations.

The hypothesis of the work: to obtain the optimal structure of the investment portfolio, it is necessary to create an algorithm for the complex application of two fundamentally different tasks. In the first, the risk criteria will be financial leverage; in the second, the integral rating of the company in the industry, the complex use involves a weighting method based on the results of the risk assessment.

Results: to obtain a CAD-based investment capital structure in the form of a DSS for investment solutions for high-tech projects.

2. Literature Foundations

In the scientific literature, the definitions of a high-tech industry are almost the same, as shown in [11–13], and basically all definitions are reduced to understanding the company's attitude to high-tech industry [14].

Some authors have studied high-tech companies [15], taking into account the industry characteristic [16–22].

The financing of high-tech production in generating cash flow is shown in Reference [23].

The articles [24–28] show the high volatility of shares of high-tech companies that have premiums and the presence of high cash flow.

Portfolio investing is an important and sought-after area of portfolio discussions. The generally accepted terms "do not put all eggs in one basket", "buy cheaper, sell more expensive" cannot be used with new technologies.

So, you need to invest in a stable company of a high-industry complex, and it is not always possible to buy cheaper and sell more expensive; it is advisable to buy shares of companies quite cheap (from the point of view of technical analysis) and own them, not sell them, but receive dividends.

The sale is possible, or the company becomes high-risk and low-profit, or the owner needs money, then you need to look for options for selling at a high price (technical analysis, author's risk indicators) [29,30].

Minimax Approach, Model, Methodology

Let m industries be considered for investment purposes, and a certain number of companies are selected in each industry; in total, n companies are involved in the analysis, distributed across m industries. Estimates of the financial leverage of companies are denoted by $FL_1 > 0, \ldots, FL_n > 0$ (the ratio of debt capital to equity, preferably less).

The integral ranks of companies (hierarchical procedure, author's approach) are denoted by $IR_1 > 0 \geq IR_2 \geq \ldots \geq IR_n > 0$ ("1" is the best, "n" is the worst). It is necessary to determine the investment shares of companies $\theta = (\theta_1, \ldots, \theta_n)$.

A prerequisite for model construction is to take into account the priority of industries to improve the rating of companies using industry-specific adjustments.

Based on the hierarchical analysis of statistical data, an integral rating of companies, V, is constructed, indexed according to the company number in the list (for the i-th company, rating, leverage level, V_i).

In order to obtain the recommended investment shares, a mathematical problem with a non-smooth functional and a linear constraint of the form is used:

$$\max_{i=\overline{1,n}} FL_i \widetilde{\theta}_i \to \min_{\widetilde{\theta}\in\Omega}, \quad \Omega = \{\widetilde{\theta} = (\widetilde{\theta}_1, \ldots, \widetilde{\theta}_n) \in R^n : \sum_{i=1}^{n} \widetilde{\theta}_i = 1\}, \tag{1}$$

the solution of the problem (1) is determined by the formulas (2)

$$\widetilde{\theta}_i = \frac{1}{FL_i \sum\limits_{k=1}^{n} (FL_k)^{-1}}, \ i = \overline{1,n}. \tag{2}$$

When taking into account the profitability as an additional constraint, the model (1) is modified, the set Ω changes to the set

$$\Omega^{\eta} = \{\widetilde{\theta} = (\widetilde{\theta}_1, \ldots, \widetilde{\theta}_n) \in R^n : \sum_{i=1}^{n} \widetilde{\theta}_i = 1, \ \sum_{i=1}^{n} \eta_i \widetilde{\theta}_i = \eta_p\}. \tag{3}$$

Accordingly, the problem (1) takes the form:

$$\max_{i=\overline{1,n}} FL_i \widetilde{\theta}_i \to \min_{\widetilde{\theta}\in\Omega^{\eta}},. \tag{4}$$

The solution of this problem is described in Reference [31].

If it is impossible to simultaneously maintain the balance of less risk—less profitability, it is necessary to use the model (1)–(2). Profitability will be taken into account when evaluating the ratings of companies at the next stage of data analysis. Profitability is considered as the ratio of profit to equity (return on equity), so the indicators of profit and equity are very important.

According to the results of the analysis of the rank of companies, which is based on a hierarchical analysis of data on their financial and economic activities, the industries are ranked according to the principle, which is a far-reaching generalization [32–34].

The essence of the method consists of a hierarchy of ranking; in essence, the indicators of the balance sheet, which are especially important for the investor.

Similar to problem (1), the problem is set:

$$\max_{i=\overline{1,n}} IR_i\hat{\theta}_i \to \min_{\hat{\theta}\in\Omega}, \Omega = \{\hat{\theta} = (\hat{\theta}_1, \ldots, \hat{\theta}_n) \in R^n : \sum_{i=1}^{n} \hat{\theta}_i = 1\}, \tag{5}$$

the solution of the problem (5) is determined by the formulas (6):

$$\hat{\theta}_i = \frac{1}{IR_i \sum\limits_{k=1}^{n} (IR_k)^{-1}}, \ i = \overline{1,n}. \tag{6}$$

The final indicator for companies is obtained by adjusting the solution of problem (1) by solving problem (5).

Let $\sum\limits_{i=1}^{n} \hat{\theta}_i \cdot \widetilde{\theta}_i = z$.

The investment shares of the i-th company are obtained according to the formulas (7):

$$\theta_i = \frac{\hat{\theta}_i \widetilde{\theta}_i}{z}, \ i = \overline{1,n}. \tag{7}$$

Accounting for the industry principle, Rank 1 is assigned to the industry whose company has the best rating, then the industries are followed in descending order of the ratings of the leading companies in the rating, and they are assigned an independent rating (rank), from the first (1) to the last (numerically equal to the number of analyzed industries).

Let us denote W_k the rank of the k-th industry according to the number of the industry in the list (by priority). Similar to task (1), for industries, the task is set:

$$\max_{i=\overline{1,n}} W_i \breve{\theta}_i \to \min_{\hat{\theta}\in\Omega}, \Omega = \{\breve{\theta} = (\breve{\theta}_1, \ldots, \breve{\theta}_n) \in R^n : \sum_{i=1}^{n} \breve{\theta}_i = 1\}, \tag{8}$$

the solution of the problem (8) is determined by the formulas (9):

$$\breve{\theta}_i = \frac{1}{W_i \sum\limits_{k=1}^{n} (W_k)^{-1}}, \ i = \overline{1,n}. \tag{9}$$

The final indicator for the companies is obtained by adjusting the solution of problem (7) by solving problem (8).

Let $\sum\limits_{i=1}^{n} \theta_i \cdot \breve{\theta}_i = zz$.

The investment shares of the i-th company are obtained according to the formulas (11):

$$\theta\theta_i = \frac{\theta_i \breve{\theta}_i}{zz}, \ i = \overline{1,n}. \tag{10}$$

This study uses companies in the oil and gas industry, so the calculations are based on formulas (1–7). The program block contains a three-step procedure.

The common scheme of CAD is shown in Figure 1.

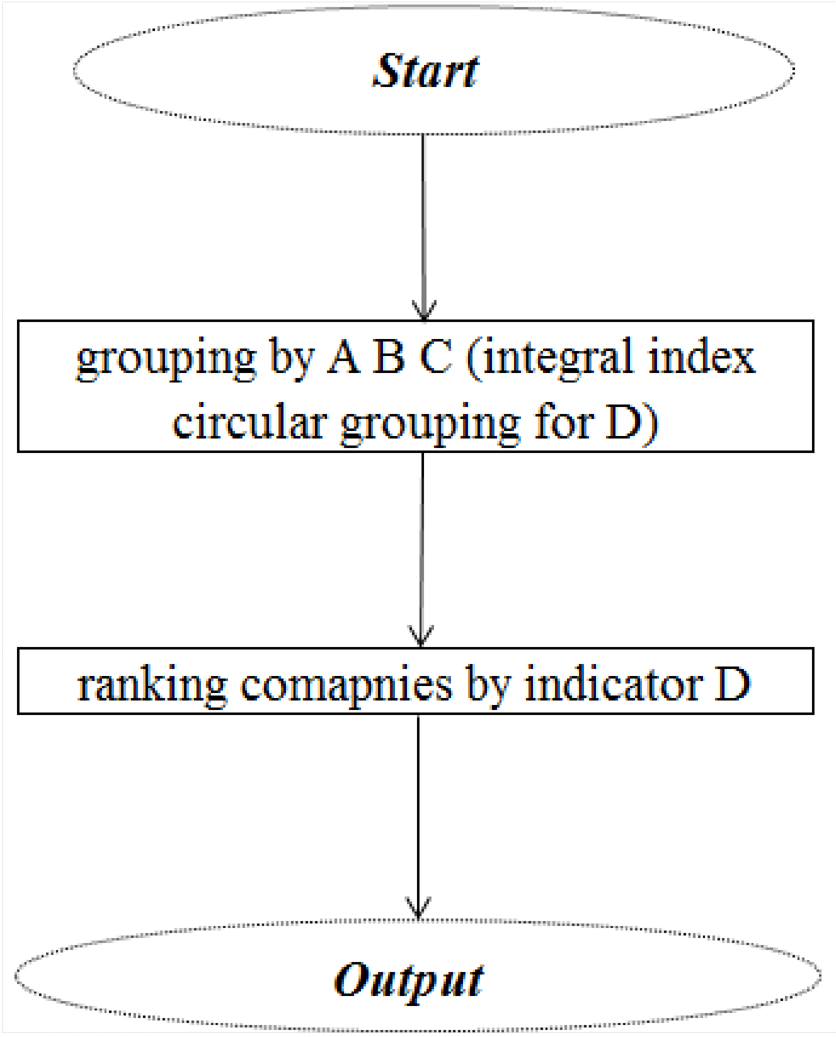

Figure 1. CAD by scheme of information flows, integrated rating.

The method of circular convolution of large companies. At the first stage, two groups are identified: the leaders (ABC indicators are above average) and the last (ABC below average). The remaining companies form a middle group, which is subject to further ranking according to the principle: from the borders to the center of the circle after the signal to stop the process is received: the presence of one or two groups of leaders and the closing ones without the possibility of allocating the middle group.

At the second stage, an integral rating is built. The indicator D is applied, first for all the leading groups, from 1 to the last, then in the central group according to the results of the hierarchical analysis, and then for the closing groups from the last to the first (boundary) (Figure 1).

Programming. Consider the procedure for estimating the parameters of the model (1)–(2) (Figure 2).

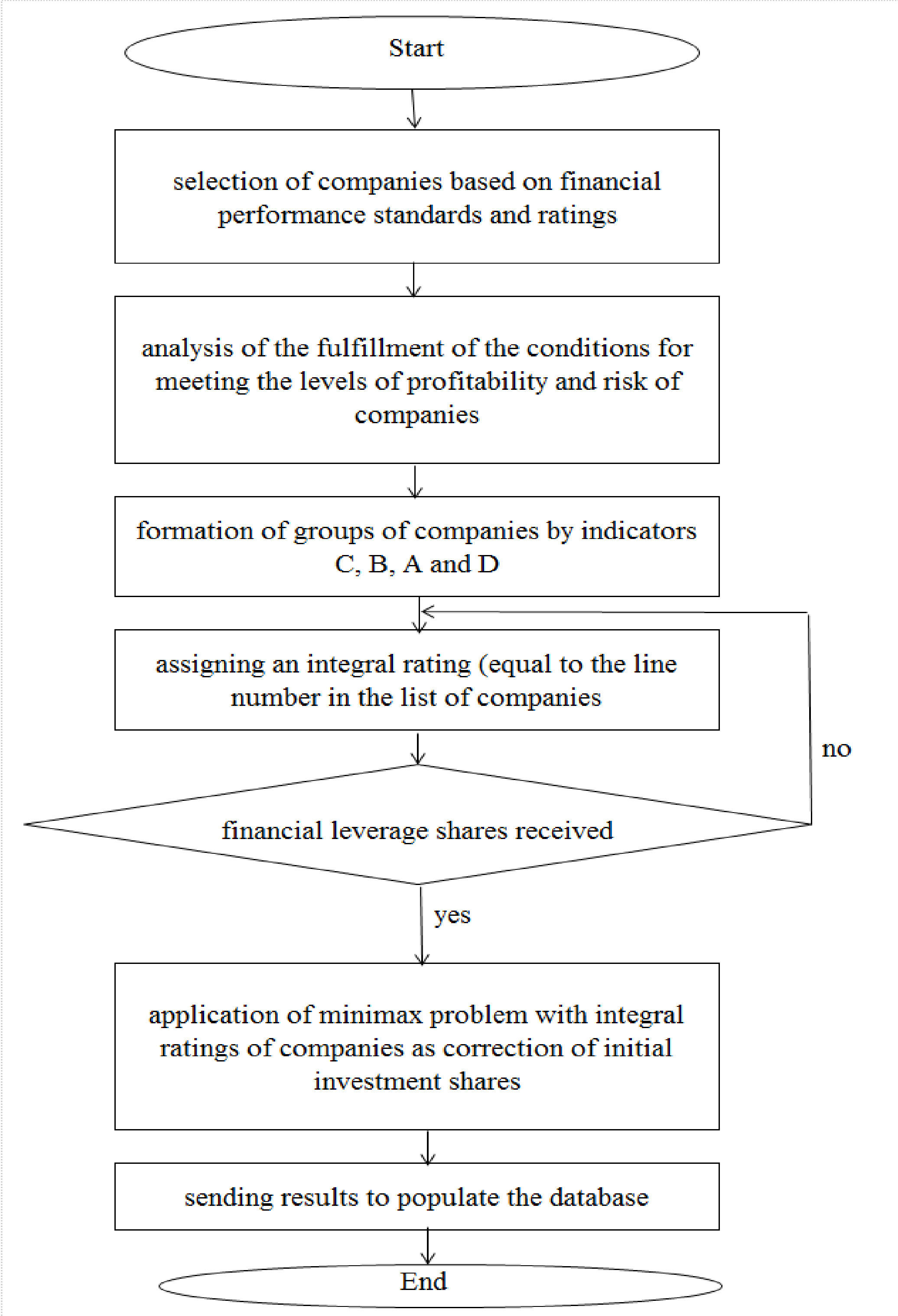

Figure 2. DSS.

3. Results

In Ref. [35], the following data are obtained (2019, Table 1).

Financial data on oil and gas companies that were used in the article can be found in Supplementary Materials.

Profitability and risk are unbalanced; for example, for PJSC Novatek, the profitability is higher than for PJSC Gazprom, and the risk is lower. This does not mean that the portfolio should include only PJSC Novatek, as the volume of production and dynamics of development and market share are important. The undisputed leader is PJSC Gazprom, which has proved itself over the years among the largest companies in Russia from various industries with high-tech development (oil and gas, electricity, banks, high-profile trade sector, metallurgy, telecommunications, etc.). In this analysis, it is necessary to apply the model (1)–(2), the restrictions are used for integral rankings-ratings of companies (hierarchy scheme) (Table 2).

Table 1. Financial analysis parameters of companies for rating.

Company, PJSC	Net Profit, Thousand Rubles	Equity Capital, Thousand Rubles	Revenue, Thousand Rubles	Assets, Thousand Rubles	Debt Capital, Thousand Rubles	Risk (Debt/Equity, Financial Leverage), Shares (%)	Profitability (Net Profit to Equity), Shares (%)
Gazprom	651,124,114	11,334,679,889	4,758,711,459	15,916,355,497	4,581,675,608	40.40%	5.70%
Lukoil	405,759,769	957,169,199	444,471,354	2,209,166,567	1,251,997,368	130.80%	42.40%
Surgutneftegaz	105,478,643	4,303,834,579	1,555,622,592	4,553,686,428	249,851,849	5.80%	2.50%
Novatek	237,224,510	718,557,978	528,544,385	899,787,613	181,229,635	25.20%	33.00%

Table 2. Solving the problem (1)–(2) for ratings.

Company	Net Profit, Thousand Rubles (Index D)	Equity Capital, Thousand Rubles (Index C)	Revenue, Thousand Rubles (Index B)	Assets, Thousand Rubles (Index A)	Place, 1—Leader (Including Revenue)	The Company's Share in The Portfolio by Rating Position
Gazprom	651,124,114	11,334,679,889	4,758,711,459	15,916,355,497	1	48%
Lukoil	405,759,769	957,169,199	444,471,354	2,209,166,567	3	16%
Surgutneftegaz	105,478,643	4,303,834,579	1,555,622,592	4,553,686,428	2	24%
Novatek	237,224,510	718,557,978	528,544,385	899,787,613	4	12%

The industry analysis in the group of the 20 largest Russian companies for the selected companies is presented in Table 3.

Table 3. Industry rating in the group of leaders of the 20 Russian companies.

Company	Rating (C, A)	Rating (C, A, B)
PJSC Gazprom	3	1
PJSC Lukoil	4	3
PJSC Surgutneftegaz	15	15
PJSC Novatek	6	6

The investment shares were estimated for the company indicators, taking into account the formulas (6)–(7). The results are shown in Figure 3.

The estimation of the investment shares, taking into account the formulas (9)–(10) for model (8), is shown in Figure 4.

2019	
Company	Invest, optimal 2019
Gazprom	20%
Lukoil	2%
Surgutneftegaz	70%
Novatek	8%
Total	100,00%

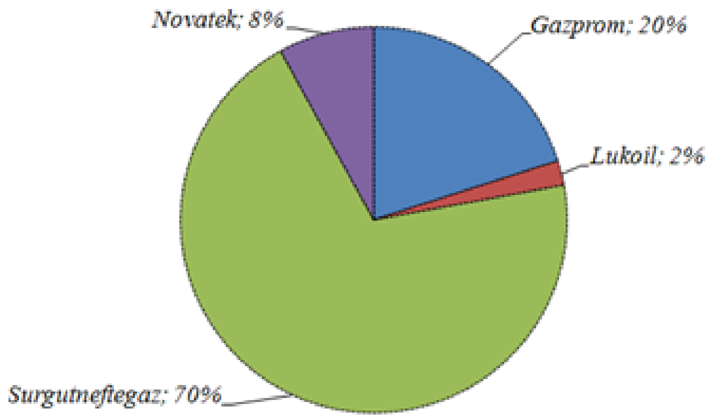

Figure 3. Optimal capital by model (6)–(7).

2019	
Company	Invest, optimal 2019
Gazprom	75%
Lukoil	3%
Surgutneftegaz	17%
Novatek	5%
Total	100%

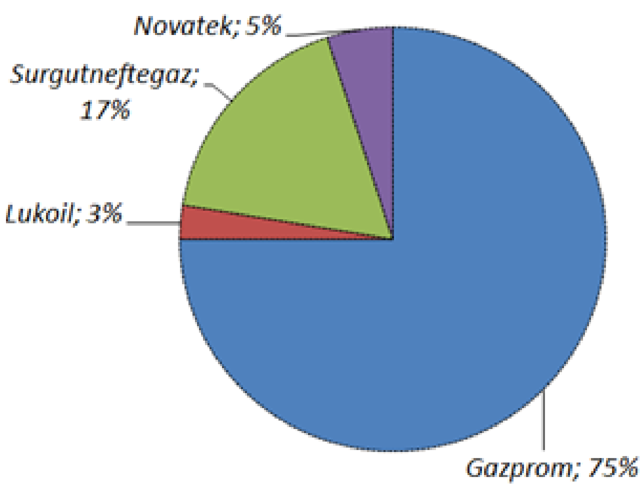

Figure 4. Optimal capital by model (8)–(9).

4. Discussion

Due to the undoubted leadership in the industry principle (among all companies in high-tech industries in Russia), Gazprom is in the first place. According to the author's method of ranking companies, only in 2016 did PJSC Gazprom lose to PJSC Sberbank, which introduced online technologies and convenient services, but in 2017 it again took first place. PJSC Surgutneftegaz and PJSC Novatek should use their industry competitive advantages to develop high-tech production, and not to compete with a leading company.

The goal of development is to balance and properly compete for resources through high-tech processing and environmentally friendly (with minimization and competent disposal of raw material waste, which is an important problem for the oil and gas industry in particular) consumption within the country. The export of raw materials should be replaced by high-tech exports of more expensive products with the competent processing of raw materials into a convenient resource for use. Companies should develop by saving raw materials that are unstructured and dangerous to the health of citizens, and by saving waste through competent high-tech processing, testing and implementation within the country, which is the main competitive advantage of the companies under consideration.

5. Conclusions

This paper considers several companies of the oil and gas complex, selected by the investor on the principle of a comprehensive solution to the problem of high-tech production and the sales of products in Russia. Since the purpose of the work is a comprehensive assessment of the stable development of companies, the profit return on investment goes by the wayside in comparison with the volume of sales of goods (resource availability), with a stable level of other indicators. It is Gazprom that comes out on top, and it is necessary to add high-tech financing for this company in the volume of high-tech products that it will master and therefore be able to produce a productive report. Projects have faded into the background, and the rapid implementation of high-tech projects using computerized CAD systems, in particular DSS in this industry, is coming to the fore. This development is associated with the subsequent growth of the investment activity of interested actors from scientifically oriented and practically financially literate citizens and persons making high-tech decisions on the status and level of the development of structures and industry complexes that are necessary for the life and high-tech development of Russia.

Supplementary Materials: A document with financial statements of the oil companies considered in the article, is available on the Internet at https://e-ecolog.ru/buh (accessed on 30 July 2021).

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Nomenclature

The following symbols are used in the article:

DSS	Decision Support System;
SAD	computer-aided design system;
m	number of industries;
n	the number of companies participating in the analysis (from all selected industries for analysis);
FL	Estimates of financial leverage, that is, the ratio of borrowed capital to equity expressed in fractions of a unit or as a percentage;
IR	integral ranks of companies (from the best, equal to one) obtained during the implementation of the author's algorithm;
Ω	there are many restrictions on the structure of the portfolio (the sum of the shares is one);

Ω^{η}	there are many restrictions on the structure of the portfolio (the sum of the shares is one and the required yield is fixed at the level of η_p, taking into account the returns of the assets included in the portfolio η_i, $i = 1, \ldots, n$;
$\widetilde{\theta}$	vector (with components that make up the investment shares, giving a total of one), for a problem with risk assessment in terms of financial leverage;
$\hat{\theta}$	vector (with components that make up the investment shares, giving a total of one), for a problem with an assessment in terms of an integral rating of companies;
θ	vector (with components that make up the investment shares, giving one in total), for the optimal portfolio structure, correction of the solution of the problem with risk assessment in terms of financial leverage by solving the problem for risk assessment in terms of integral rating, the solution of the second problem is the correction coefficients for optimizing the solution of the first problem;
W_i	industry rank, for further optimization of a portfolio solution containing companies from several industries;
$\breve{\theta}$	vector (with components that make up the investment shares, giving a total of one), for a problem with an assessment in terms of an integral rating of industries;
$\theta\theta$	vector (with components that make up the investment shares, giving one in total), for the optimal portfolio structure, correction of the solution of the problem with risk assessment in terms of financial leverage by solving the problem for risk assessment in terms of integral rating, the solution of the second problem is the correction coefficients for optimizing the solution of the first problem, as well as taking into account the correction of the solution for each company taking into account the industry attribute (solving the problem of optimizing the rating of industry positions in the portfolio), if there is one industry, then the result coincides with the calculation;
z, zz	intermediate indicators that do not have significant significance in terms of their interpretation.

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