DOI: 10.17747/2618-947X-2023-2-136-149
UDC 338

Strategic management of the economic sustainability of a company in the paradigm of fuzzy logic

Yu.A. Malyukov[1]
A.O. Nedosekin[2]
Z.I. Abdoulaeva[3]
[1] The Kosygin State University of Russia (Moscow, Russia)
[2] 'Institute of Financial Technologies' LLC (Saint Petersburg, Russia)
[3] North-Western State Medical University named after I.I. Mechnikov (Saint Petersburg, Russia)

Abstract

The theory of economic resilience is actively developing in Russian and foreign scientific studies. Most of them lack a comprehensive approach to the issue of resilience, the ability to assess the behaviour of economic systems under conditions of uncertainty and to offer optimal solutions to ensure the resilience of economic systems (enterprises, industries) in difficult conditions. It is necessary to develop optimal algorithms for managing economic systems under adverse effects (AE) of a natural, technological, or military nature. The article describes the method of managing economic resilience in three-dimensional spaces: 'stability – efficiency', 'risk – efficiency', and 'chance – efficiency'. The results of three approaches to resilience management are compared.

It can be tentatively assumed that the stability of an individual company is ensured if the economic stability index RI exceeds the level of 0.6 and the return on equity is at least 20% per annum. More generally, in the 'resilience – efficiency' space, the domain of stable states of the enterprise is described by a fuzzy parabolic R lens. In the 'risk – efficiency' and 'chance – efficiency' domains, the space of optimal solutions is represented by a set of non-dominated Pareto alternatives, united by a fuzzy parabolic efficient bound of the solution portfolio set. The organisation can control its level of economic resilience within multiple representations and act according to a predetermined plan in the event of a temporary loss of resilience. The research is original, using the methods of fuzzy set theory and soft computing. A technology has been proposed to ensure the economic resilience of systems operating in difficult conditions (e.g. in new regions of the Russian Federation where large-scale military actions are taking place). This makes the study highly relevant and practical.

Keywords: resilience index, return on equity, adverse effects, favorable external influences, risk, chance, R lens, matrix aggregate calculator.

For citation:

Malyukov Yu.A., Nedosekin A.O., Abdoulaeva Z.I. (2023). Strategic management of the economic sustainability of a company in the paradigm of fuzzy logic. *Strategic Decisions and Risk Management*, 14(2): 136-149. DOI: 10.17747/2618-947X-2023-2-136-149. (In Russ.)

模糊逻辑范式内企业经济可持续性的战略管理

Yu.A. Malyukov[1]
A.O. Nedosekin[2]
Z.I. Abdoulaeva[3]
[1] 俄罗斯国立A. H. 柯西金大学（俄罗斯莫斯科）
[2] "金融技术研究所"有限责任公司（俄罗斯圣彼得堡）
[3] 以梅契尼科夫名字命名的西北国立医科大学（俄罗斯圣彼得堡）

摘要
俄罗斯和外国的科学研究都在积极发展经济可持续性理论。然而，这些研究大多缺乏处理可持续性问题的综合方法、在不确定条件下评估经济系统行为的能力以及提供最佳解决方案，确保经济系统（企业、行业）在复杂条件下的可持续发展。有必要开发最佳算法，以便在自然、人为或军事性质的不利外部影响下管理经济系统的可持续性。本文章描述了三个坐标空间中经济可持续性管理的顺序："可持续性——效率"、"风险——效率"和"机会——效率"。而且对已确定的三种可持续性管理方法的结果进行比较。
可以初步认为，如果经济可持续发展 RI 指数超过 0.6，且股本回报率每年至少达到 20%，则单个企业的可持续发展能力就得到了保证。从更广泛的角度看，在"可持续性——效率"空间中，企业的稳定状态区域可以用模糊抛物线 R 镜头来描述。
在"风险——效率"和"机会——效率"空间中，最优解的领域是在帕累托效率意义上非优势的备选方案集合，它们由投资组合解集的模糊抛物线有效边界联合起来。企业可从以下几个方面监测其经济可持续性水平并在暂时失去稳定的情况下按照已知计划行事。
本研究具有独创性，应用了模糊集理论和软计算方法。作者提出了以确保复杂工作条件下系统的经济可持续性技术（例如，在俄罗斯联邦正在开展全面军事行动的新地区）。这决定了所开展研究的极端相关性和实际意义。
关键词： 经济可持续性索引、股本回报率、不利影响、有利影响、风险、机会、R 镜头、矩阵计算器。

供引用:
Malyukov Yu.A., Nedosekin A.O., Abdoulaeva Z.I.（2023）. 模糊逻辑范式内企业经济可持续性的战略管理。战略决策和风险管理，14（2）：136–149. DOI: 10.17747/2618-947X-2023-2-136-149.（俄文）

Introduction

In order to clearly formulate the research problem of this article, it is first necessary to define the terms. Here and in the following, the efficiency of the economic system of a company is understood as the ability of a company to organise the production of a target product in such a way that the resulting relationships between the company and all the important stakeholders are mutually satisfactory. The stakeholders of the firm are understood as consumers of the target product, suppliers, banks, employees, investors (shareholders) and the state, represented by its federal and regional institutions. This definition of efficiency does not focus on the target product, but on the exchange of value that takes place in the business environment that accompanies the preparation, release and delivery of the product to the consumer.

This immediately raises the question of the efficiency measure. Traditionally, in the works of the fuzzy economics school [Malyukov et al., 2023a; Nedosekin et al., 2020], as a basic measure of efficiency we consider the return on equity (ROE) as a percentage per annum. The main explanation for our choice is as follows. There are two chains: the chain of adding value to the target product and the chain of distributing the benefits associated with the sale of the product, which in a sense mirrors the first chain. If the entrepreneur is at the beginning of the value chain (initiates the business, invests capital), he is at the end of the benefit distribution chain. This can be easily observed in the example of a report on the financial position of an organisation. The first in the chain of distribution of goods is, of course, the consumer, whose benefit is concentrated in the target product. By paying for a product, the consumer creates the basis for the distribution of benefits further down the chain. The second link in the chain is the supplier of raw materials and inputs, followed by the employees and their wages. The state tirelessly collects tribute from the company in the form of various taxes; the banks do not lag behind the state with their interest rents. The net profit from the results of all the business activities of the enterprise goes to the owner as a reward for a successfully organised business - in the last place, at the last moment. As a risk premium, the owner naturally demands a higher return on invested capital, i.e. ROE at the level of at least three deposit rates in a reliable bank. In today's conditions (2023), this becomes a business covenant at the level of 20% per annum in roubles.

A rate of return on equity in excess of 20% per annum is formulated by the owner under normal operating conditions.

When the situation has changed and conditions have become abnormal, the owner finds himself at a crossroads:

- in extreme operating conditions, when the economic system of companies and industries is affected by adverse external influences of a military, natural or man-made nature, the owner thinks about preserving the business and the efficiency criterion recedes into the background. It turns out that it is sufficient to ensure the break-even point of the enterprise, i.e. to require the return on equity above 0. The task of ensuring economic sustainability, understood in the sense of resilience, comes to the fore [Nedosekin et al., 2020; Malyukov et al., 2023a; 2023c;], i.e. the ability of the enterprise to continue functioning in the conditions of adverse external influences, even with reduced efficiency;
- in the paradigm of public-private partnership mobilisation, the enterprise is included in the chain of implementation of state orders (for example, defence). In this case, the entrepreneur has the right to return to the requirement of ROE above 20% per annum at the cost of a partial loss of his economic independence (payment for maintaining economic stability under state patronage). We will explain this idea in more detail outside the scope of this article;
- if a company opens up a new market niche and has the chance to enter it with a new product (blue ocean paradigm [Kim, Mauborgne, 2015]), then this should be considered as an opportunity (opportunity in the sense of the SWOT matrix), i.e. as a kind of favourable impact on the economic system of the company. Of course, when an entrepreneur decides to develop and implement an innovation, there is a risk that the firm will lose its level of sustainability (at least temporarily), and this is an additional risk. As a premium for this risk, the owner expects a return on the capital invested in innovation, which is already at a triple-digit level. The ROE covenant of more than 100% per annum is not extreme for innovation. Moreover, in a number of cases, such a level of ROE is achieved in relation to the company's total equity. For example, in 2020, according to the Finance.Yahoo resource, international companies with the tickers EVR.L, CROX and LMT exceeded the ROE level of over 100% per annum. The issue of economic sustainability in the sense of resilience is discussed in more detail in [Holling, 1973; Holling, 1996; Gunderson and Pritchard, 2002; Perrings, 2006; Walker et al., 2006; Hill et al., 2008; Martin, 2011; Martin, Sunley, 2013; Muller et al., 2013; Hosseini et al., 2016; Buheji, 2018; Sabatino, 2019; De Graaf et al., 2000; Nedosekin et al., 2020].

As a measure of sustainability, Fuzzy Economics scientific school uses the sustainability index (RI), which takes values from 0.1 (very low level of sustainability) to 0.9 (very high level of sustainability). The assessment of RI for companies can be carried out using an express method with the help of the Matrix Aggregate Calculator (MAC, [1]) technology, as well as according to a detailed scheme - with the help of the 4x6 strategic matrix technology [Malyukov et al., 2023c]. The corresponding analysis can be carried out both for individual enterprises and for groups of enterprises (sectors, industries).

Now let's determine the risks and opportunities. In monographs [Kozlovsky et al., 2016; Abdulaeva, Nedosekin, 2017], an independent methodology for analysing the risks and opportunities of economic systems was proposed, based on a number of key definitions:

- threat - a situation associated with an unfavourable effect on the system;
- opportunity - a situation associated with a favourable effect on the system;
- weakness - deficiency, lack of effectiveness, target for threat;
- strength - excess, competitive advantage, target for opportunity;
- negative - a state of the system associated with a violation of normative levels 'down';
- positive - a state of the system associated with a violation of the normative levels 'up'.

Then the definition of risks and opportunities might look like this:

$$Risk = Poss\,\{Negative \mid Threat \oplus Weakness\},$$
$$Chance = Poss\,\{Positive \mid Oportunity \oplus Strength\}, \quad (1)$$

where *Poss* is the 'opportunity' sign, | - the 'provided' sign, ⊕ - the overstrike, superposition sign.

In a 4x6 matrix, risks and opportunities have their own separate places. At the highest level of the matrix's strategic presentation (the 'Impact' row), the integral risks and opportunities for the company/industry are presented.

Thus, when managing the sustainability of his company, the entrepreneur or his delegate (CEO) must simultaneously keep all four key indicators (efficiency, sustainability, risk, opportunity) in mind and look for target (desirable) points for positioning on a number of the most representative coordinate planes. The article presents the results of research in three of these planes: RI - ROE, Risk - ROE and Chance - ROE. Each of these planes provides the decision maker with a wealth of material for understanding.

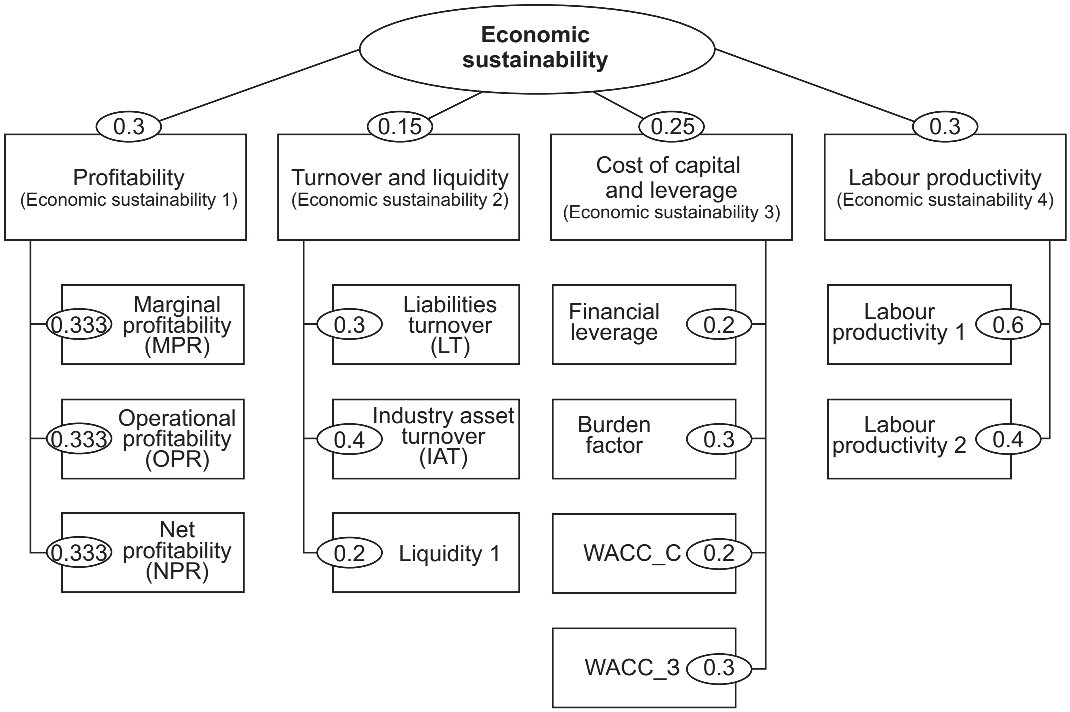
1. Methods for researching the sustainability of companies and industries

1.1. Assessing company sustainability using MAC technology

In our research over the past eight years, we have observed more than one hundred of the largest international companies, grouped into seven industry groups, namely:

- C11 - oil and gas sector;
- DJ27 - metallurgy;
- DK29 - general machine building;
- DL31 - electric machine engineering;
- E40 - production and distribution of electricity, heat and water;

Fig. 1. Hierarchical tree of support factors



Source: [Malyukov et al., 2023a].

- DB - light industry (manufacture of clothing and footwear);
- AA01 - agriculture (food production).

For each enterprise, we simultaneously diagnose twelve supporting factors (Fig. 1) and two integral factors: RI and ROE.

ROE is calculated using the classic DuPont formula:

ROE = Net profit / Equity capital = Net profitability × × Liabilities turnover × (1 + Financial leverage), (2)

The *RI* index, in turn, is calculated using the double convolution method [Nedosekin et al., 2020]:

$$RI = \sum_{i=1}^{N} p_i \sum_{j=1}^{M} y_i * \mu_{ij}, \quad (3)$$

where p is a set of support factor weights, y is an anchor point vector {0.1, 0.3, 0.5, 0.7, 0.9}, μ is a matrix whose rows are support factors with their own weights; columns are qualitative gradations {OH, H, Cr, B, OB}, indicating very low, medium, high and very high levels of factors. At the intersection of the rows and columns in the matrix μ there are functions of membership of quantitative levels of factors to qualitative gradations in accordance with previously defined industry standards for all factors.

1.2. Building an industry R lens

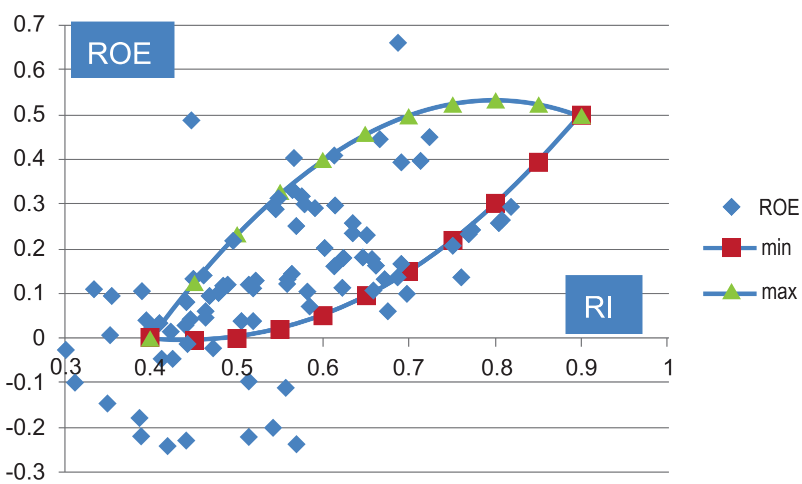
When all the measurement points have been carried out as part of the study in the previous subsection of the article, it is possible to construct industrial R lenses according to the methodology described in [Kozlovsky et al.] The R lens is actually a fuzzy function in the form of a parabola.

Fig. 2 shows the resulting stability analysis data (in the form of isolated points) and the boundaries of the covering R lens (in the form of solid lines).

The R lens is designed to pass through the following four points:

- the left point with coordinates (0.4, 0%). It is assumed that when RI < 0.4, stable net profit generation by the company is impossible;
- the bottom point with coordinates (0.6, 5%). RI = 0.6 is a fairly high level of stability and must be accompanied by profitability at least at the level of the deposit rate in a reliable bank;

Fig. 2. Source data and R lens (DB industry)



Source: compiled by the author.

Table 1
Industry indices RI

Year	Ind_RI для отраслей				
	C11	DJ27	DK29	DL31	E40
2015	0.398	0.368	0.518	0.389	0.445
2016	0.356	0.371	0.490	0.424	0.448
2017	0.434	0.409	0.516	0.380	0.473
2018	0.469	0.458	0.476	0.395	0.461
2019	0.418	0.399	0.463	0.442	0.468
2020	0.310	0.376	0.422	0.421	0.438
2021	0.459	0.533	0.499	0.490	0.485
2022	0.506	0.581	0.498	0.417	0.476

Source: [Nedosekin et al., 2023].

- the upper point with coordinates (0.6, 40%). As can be seen from Fig. 2, some companies easily cross this bar (albeit at the cost of a loss of stability). This is largely influenced by the insufficient amount of equity (as an alarm bell before going into negative equity);
- the right point with coordinates (0.9, 50%). This point is located in a rather sparse space of the initial data and expresses a certain unattainable ideal of profitability while ensuring maximum stability.

The points entered correspond to an R lens with the following regression boundary equations:

$$ROE_{min} = 2.5 \times RI^2 - 2.25 \times RI + 0.5,$$
$$ROE_{max} = -3.3334 \times RI^2 + 5.3334 \times RI - 1.6. \quad (4)$$

The coefficients in regression equation (4) were obtained using an online calculator[1].

A comparison of the original data array and the coordinates of the R lens shown in Fig. 2 shows that approximately half of the measuring points are outside the lens, i.e. they are characterised by a temporary loss of stability. In the best case scenario, there has been a critical drop in equity and it must be replenished as soon as possible. Sometimes (very rarely) there is simply too much equity and it is not working well - either capital has to be withdrawn from the business or financial leverage has to be increased. In the worst case, the company finds itself in a temporary loss zone: equity is being used up and the leak in the hold needs to be fixed before the ship sinks.

Table 2
Industry indices ROE

Year	Ind_ROE for the industries				
	C11	DJ27	DK29	DL31	E40
2015	0.210	–0.252	0.273	0.018	0.030
2016	0.027	0.028	0.627	0.107	0.344
2017	0.070	0.068	0.432	–0.001	0.134
2018	0.110	0.122	0.258	–0.219	0.114
2019	0.072	0.013	0.247	0.014	0.102
2020	–0.085	0.115	0.133	0.104	0.080
2021	0.126	0.208	0.171	–0.012	0.091
2022	0.183	0.165	0.181	0.066	–0.037

Source: [Nedosekin et al., 2023].

[1] IFEL.ru: Online calculator for R lens identification. http://an.ifel.ru/js/r-lens.html.

1.3. Construction of industry sustainability indexes

If 20 companies are selected within an industry segment and measurements are taken over 8 years, this gives 20 × 8 = 160 measurement points. This is a sufficient number of measurements to build a preliminary model description of the industry by entering industry indices for each of the selected indicators. The following rule is valid. If X_{it} is a measurement of factor X for the *i*-th enterprise in the industry segment, carried out in year number *t*, and A_{it} is the balance sheet currency of the *i*-th enterprise in year *t*, then the industry index *Ind_X(t)* should be found using the formula [Nedosekin et al., 2023]:

$$Ind\_X(t) = \sum_{(i)} A_{it} \times X_{it} / \sum_{i} A_{it}. \quad (5)$$

Tables 1 and 2 summarise the indicators for the industry indices RI and ROE.

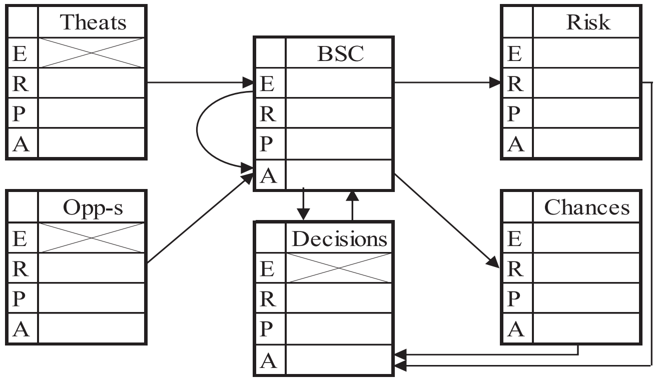
Similar indices can be constructed for the remaining 12 selected industry parameters using relationship (5).

All historical data on industry indices can be used to feed industry sustainability models and to calibrate the corresponding model factors. However, for the purpose of forecasting the levels of industry indices, it is appropriate to use fuzzy numbers and fuzzy functions. The information contained in the historical data is sufficient to make a fuzzy prediction for a future year (2023). This forecast can be made in the form of fuzzy numbers using the following relationships:

$$Min\_I\_X = min_{(t)}\ Ind\_X(t),$$
$$Av\_I\_X = average_{(t)}\ Ind\_X(t),$$
$$Max\_I\_X = max_{(t)}\ Ind\_X(t). \quad (6)$$

Here *FI = FI (Min_I_X, Av_I_X, Max_I_X)* – is a triangular fuzzy number with abscissae expressing the minimum, average and maximum values of the *I_X* measurements for the whole observation period. This is the forecast of the index for the coming year.

Fig. 3. Matrix 4×6



Sources: [Nedosekin et al., 2020; Nedosekin et al., 2023a; 2023b].

Table 3 summarises data on triangular fuzzy numbers within individual industry sustainability indices for industry C11 (as a separate industry example). We can do this work both within industries and within individual companies.

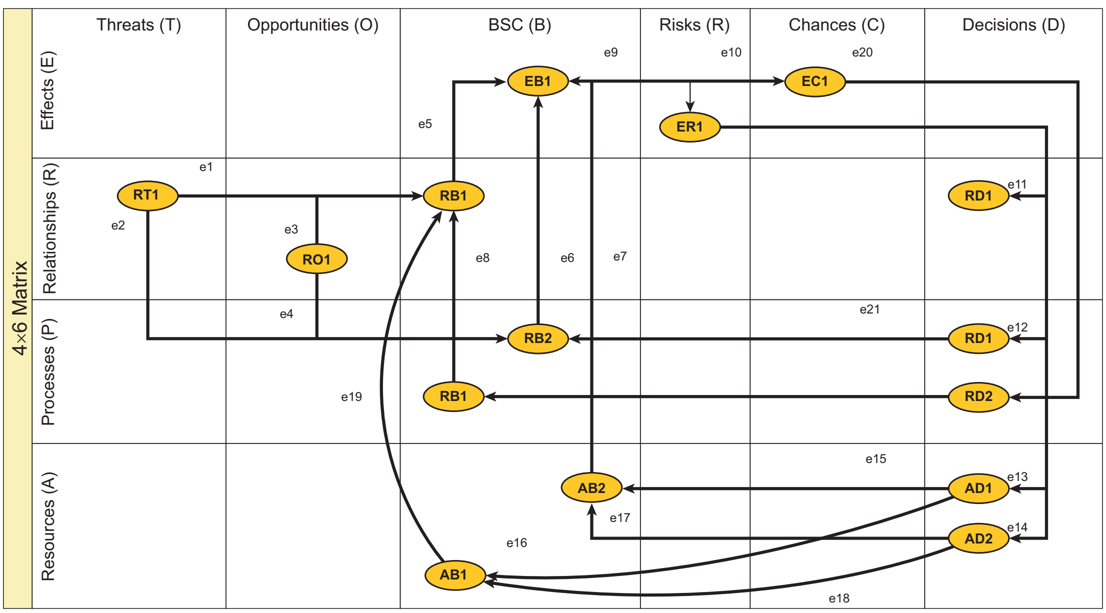
1.4. Formation of a 4x6 matrix

The 4×6 matrix is a system of six interconnected strategic cards (Fig. 3), each with four strategic perspectives.

Card names:

- Threats – threat card;
- Opp-s – opportunity card (opportunities in terms of the SWOT matrix);
- BSC – balanced score card
- Risk – risk card;
- Chances – chance card;
- Decisions – decision card.

Fig. 4. The simplest example of a 4×6 industry matrix



Source: [Malyukov et al., 2023b].

Table 3
Fuzzy industry sustainability factors (C11)

Factor code	Sustainability index	FI for C11 indices		
		Min_I_X	Av_I_X	Max_I_X
Z1	Ind_MP	0.178	0.301	0.368
Z2	Ind_OP	–0.021	0.079	0.155
Z3	Ind_ЧP	–0.055	0.044	0.104
Z4	Ind_ОбП	0.557	0.745	1.106
Z5	Ind_ОбОА	2.672	4.136	9.909
Z6	Ind_Л1	1.165	1.221	1.308
Z7	Ind_ФР	1.005	1.304	1.512
Z8	Ind_KO	0.074	0.323	0.789
Z9	Ind_WACC_C	0.042	0.056	0.081
Z10	Ind_WACC_З	0.013	0.019	0.048
Z11	Ind_ПТ1	1610	2533	4040
Z12	Ind_ПТ2	–128	106	411
RI	Ind_RI	0.310	0.419	0.506
ROE	Ind_ROE	–0.085	0.066	0.183

Source: [Nedosekin et al., 2023].

Table 4
Indicators with 4×6 matrix

Indicator code	Indicator name	Scale
RT1	Industry demand contraction index	% to previous year
RO1	Industry demand expansion index	% to previous year
EB1	Return on equity index (ROE)	% per annum
RB1	Net profitability index	%
PB1	Labour productivity index	thousand dollars in revenue per employee per year
PB2	Liability turnover index	once a year
AB1	Weighted average cost of borrowed capital index	% per annum
AB2	Financial leverage index	dimensionless
ER1	Integral industry risk	from 0 to 1
EC1	Integral industry chance	from 0 to 1
RD1	Industry decision factor 1: increase in net profitability	%
PD1	Industry decision factor 2: increase in liability turnover	once a year
PD2	Industry decision factor 3: increase in labour productivity	thousand dollars in revenue per employee per year
AD1	Industry decision factor 4: increase in financial leverage, decrease in the weighted average cost of borrowed capital	by leverage - dimensionless, by weighted average cost of capital - % per annum
AD2	Industry decision factor 5: increase in financial leverage, decrease in the weighted average cost of borrowed capital	by leverage - dimensionless, by weighted average cost of capital - % per annum

Source: [Malyukov et al., 2023b].

Names of strategic perspectives:

- A - assets;
- P - processes;
- R - relationships between the industry and its key stakeholders (consumers, suppliers, banks, employees, government, etc.);
- E - effects - the results presented by the industry.

The simplest example of a 4×6 industry matrix [Malyukov et al., 2023b] is shown in Fig. 4. Indicators on strategic maps are labelled according to a single XYZ principle, where X is the code of the strategic perspective, Y is the code of the card, Z is the number of the indicator in order (within a cell of the matrix). The indicators shown in Fig. 4 are summarised in Table. 4.

The data in Table 4 should be accompanied by the following comments:

- the matrix model is mainly built on indices obtained for the enterprises included in the industry using average weighting methods of type (5);
- the indicators are represented in a 4x6 matrix model either as fuzzy numbers or as Zadeh linguistic variables;
- the model is dynamic; there are time lags between observations, decisions and the reaction of the industrial system to decisions;
- Decisions affecting the industry are made by the government and are aimed at increasing the sustainability of the industry. Such decisions, made within the framework of the Public-Private Mobilisation Partnership (PPMP), include:
  1) Formation of a unified pricing policy within the framework of specially created inter-industry syndicates, with the net profitability (NPR) of all key players in the syndicate being fixed at the level of NPR = 5-7%;
  2) Voluntary transfer of part of the long-term industrial assets to the State Property Fund under the conditions of a repayable industrial mortgage at the rate of 3% per annum, bringing the liability turnover (LT) to the level of LT = 1.5 times per annum;
  3) Development of a unified industrial system of personnel motivation for the task of developing new market niches and technologies for closing these niches, with the labour productivity in terms of sales (LP1) being brought to a level corresponding to the industrial quality grade ‘B’ (high level);
  4) Establish a factoring programme for the industry’s suppliers at a rate of 2% per annum, bringing the industry’s average financial leverage (FL) to a level of FL = 1.6. This decision, taken independently of other decisions, should also bring the Weighted Average Cost of Capital (WACC_3) to the level of WACC_3 = 2% per annum;

Table 5
Relationships between indicators in a 4×6 matrix

Communication cipher	Source node	Receiver node	Communication entity
e1	RT1	RB1	Fall in industrial demand leads to decline in NPR
e2	RT1	PB2	Falling industrial demand leads to lower LT
e3	RO1	RB1	Growing industrial demand drives growth in NPR
e4	RO1	PB2	Growing industrial demand drives growth in LT
e5	RB1	EB1	NPR directly affects ROE (Dupont formula)
e6	PB2	EB1	LT directly affects ROE (Dupont formula)
e7	AB2	EB1	FL directly affects ROE (Dupont formula)
e8	PB1	RB1	Increase in LP1 leads to increase in NPR
e9	EB1	ER1	Decrease in ROE leads to increase in integral risk
e10	EB1	EC1	Increase in ROE leads to increase in integral Decision 1
e11	ER1	RD1	An increase in integral risk triggers the start of Decision 2
e12	ER1	PD1	An increase in integral risk triggers the start of Decision 3
e13	ER1	AD1	An increase in integral risk triggers the start of Decision 4
e14	ER1	AD2	An increase in integral risk triggers the start of Decision 5
e15	AD1	AB2	Decision 4 causes FL to increase
e16	AD1	AB1	Decision 4 causes WACC_3 to decrease
e17	AD2	AB2	Decision 5 causes FL to increase
e18	AD2	AB1	Decision 5 causes WACC_3 to decrease
e19	AB1	RB1	Decreasing WACC_3 causes FL to increase
e20	EC1	PD2	Increasing the integral chance causes Decision 3 to start
e21	PD1	PB2	Removal of obsolete funds leads to increase in LT
e22	PD2	PB1	An increase in the quality of motivation leads to an increase in labour productivity.

Source: [Malyukov et al., 2023b].

5) State industry programme for the leasing of new technologies to industry at a rate of 2% per annum.

If the above solutions 1-5 achieve their objective, the industry will achieve an investment-acceptable level of return on equity.

ROE = 20% per annum (three interest rates for a deposit in a reliable bank). This is a necessary condition for the industry to reach a level of economic sustainability with a qualitative grading no worse than 'B'.

The relationships between the indicators are shown in Table 5.

1.5. Industry risk assessment

From the data in Table 3, the main strengths, weaknesses, opportunities and threats (traditional components of the SWOT matrix) are as follows:

Strengths:

- there is no significant dependence on capital and related rents, financial leverage is relatively low;
- high labour productivity (up to $4 million in revenue per employee per year);
- good margin.

Weaknesses:

- the industry is unattractive for investment (weighted average ROE level above 20% per annum);
- low turnover of all assets (the industry is overloaded with production assets);
- the sustainability of the industry is below average.

Opportunities:

- There is potential to increase ROE to investment levels;
- there are mechanisms to increase the sustainability of the industry (at the level of government regulation);
- as a result of the special military operation, the redistribution of oil and gas flows leads to the transfer of corresponding production from the Russian Federation to the USA (2022 experience).

Threats:

- significant volatility in commodity prices leads to the phenomenon of market compression and a corresponding drop in profitability throughout the year, including the emergence of massive losses for companies in the industry;
- the same market compression is caused by a large-scale pandemic (the experience of 2020) due to a reduction in inter-industry demand.

Determining the components of the SWOT matrix is a useful exercise aimed at identifying targets for threats and opportunities. In the model, such targets need to be represented by exogenous parameters.

Let's estimate the risk of unprofitability for the oil and gas sector using the Ind_NPR index, the triangular number Ind_NPR = (-0.055, 0.044, 0.104) taken from Table. 1. In this case, taking into account (1)

Risk = Poss {Ind_NPR < 0} = 0.122. (7)

Risk assessment using an online calculator[2], Standard risk levels have been established:

- acceptable and irreducible: Risk < 0.15;
- borderline: 0.15 < risk < 0.2;
- unacceptable: Risk > 0.2. (8)

According to the classifier (8), the risk of loss on the sector index is acceptable. In order for the negative of unprofitability to materialise, the industry would have to experience the threat of a pandemic again, as it did in 2020. However, as such a negative event has already occurred in the past and the industry has learnt the right lessons in dealing with a catastrophic drop in production, the possibility of the industry suffering a loss in a similar adverse impact scenario is considered to be tolerably low.

1.6. Integral chance estimate

Let's use the index Ind_ROE > 0.2 to assess the likelihood of industry C11 reaching the investment level. If nothing is done, there is no chance of such an outcome (all abscissa of Ind_ROE from Table 3 are less than 0.2). Let's consider the option of government support for the industry in an international format as part of a programme to radically increase the turnover of the industry's assets. One possible option here is the inclusion of a reverse production mortgage, whereby the fixed assets of oil and gas companies are transferred to the government's balance sheet in exchange for the corresponding rent.

Let us assume that, as a result of the measures taken, the strictly defined standard level Ind_LR = 1.5 times per year is reached. This is in accordance with the Dupont formula (2) for the data in Table. 3 gives an expectation of Ind_ROE = ={- 0.165, 0.152, 0.391}. Then

Chance = Poss {Ind_ROE > 0.2} = 0.205. (9)

Estimation (9) was obtained using the same calculator [Martin, Sunley, 2013] with all initial data transformed to negative values. This technique can in some cases avoid the use of more complex analytical relationships for chance analysis.

Standard chance levels are defined in [Kozlovsky et al., 2020]:

- incentive chance: 0.75 < Chance < 1;
- borderline chance: 0.5 < Chance < 0.75;
- unacceptable chance: Chance < 0.5. (10)

According to the normalisation (10), the probability of reaching the investment level is lower than the normatively acceptable level. This means that simply increasing asset turnover is not a sufficient measure to reach the investment level ROE in the industry; additional efforts need to be made. Such additional measures include, in particular, government factoring of the supplier.

1.7. Pareto portfolio management

If we define a space (X, Y) of dimension 2 and specify two points with coordinates (X1, Y1) and (X2, Y2), then these points form a pair of non-dominated Pareto alternatives[3], if the logical condition is satisfied:

(X1 > X2 И Y1 > Y2) OR (X1 < X2 И Y1 < Y2). (11)

Condition (11) is true if the coordinates X and Y form an oppositional pair (competing in meaning), e.g. 'risk-return'. If

[2] IFEL.ru: Online risk assessment calculator. St Petersburg, 2023. http://an.ifel.ru/js/risk-calculator.html.

[3] https://ru.wikipedia.org/wiki/Эффективность по Парето.

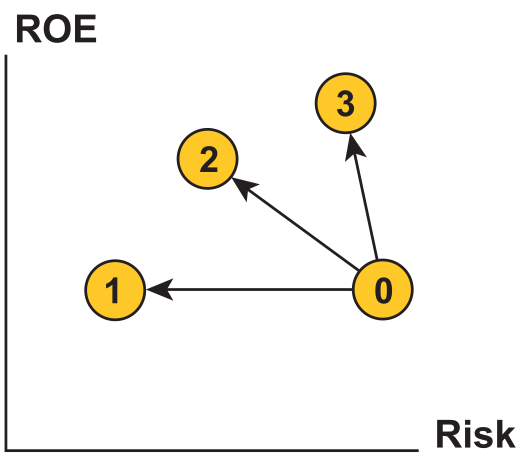
X and Y are not oppositional, then condition (11) is replaced by condition (12):

(X1 > X2 И Y1 < Y2) OR (X1 < X2 И Y1 > Y2). (12)

The set (portfolio) of representative points can be continuous or discrete. A typical example of the former is a portfolio set for the stock market in the 'risk – return' coordinates. In all cases, Pareto optimisation involves selecting all non-dominated alternatives from the portfolio; in the continuous case, the corresponding set is called the effective bound.

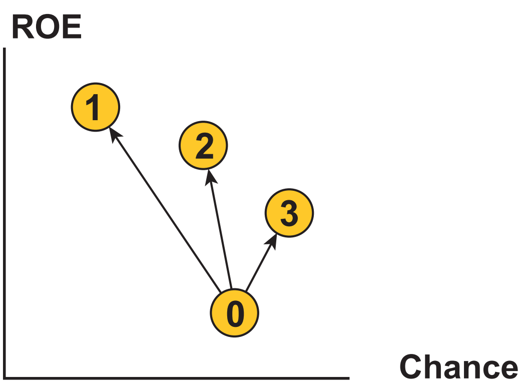
If we are dealing with a company, each of the possible solutions (decision map in a 4×6 matrix) to bring the company to a new state (more stable or more strategically promising) is a representative point in the 'Risk - ROE' or 'Opportunity - ROE' spaces. If the representative point of the solution is not dominated by other points in the portfolio, the solution is optimal. Figures 5 and 6 show the corresponding cases of anti-risk and pro-chance solutions. By default, the initial representative point of the company is dominated by all other points, otherwise there is no point in making appropriate decisions.

Fig. 5. Portfolio of anti-risk solutions in 'Risk – ROE' coordinates



Source: compiled by the authors.

Fig. 6. Portfolio of random solutions in 'Chance – ROE' coordinates



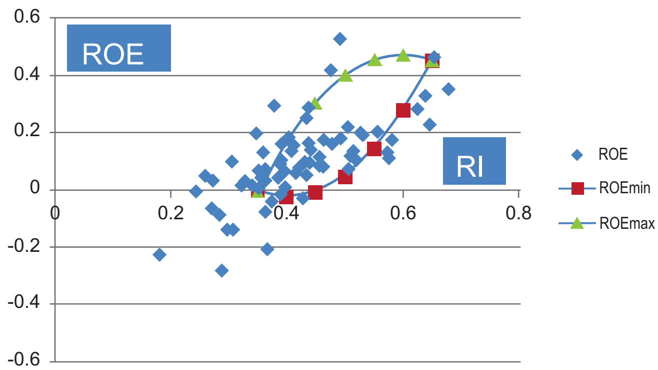
Source: compiled by the authors.

2. Calculation part of the study

2.1. Stability management in 'RI – ROE' coordinates

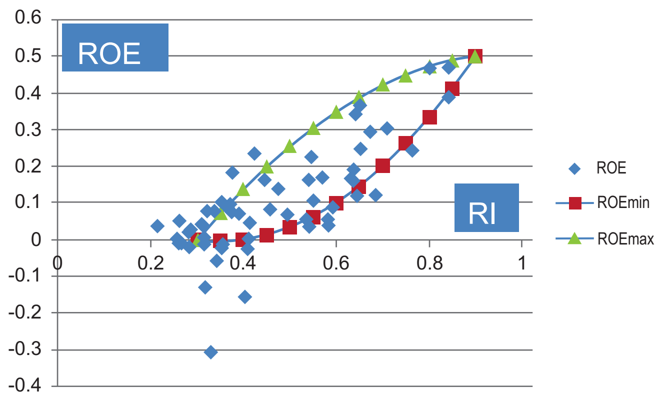
Figures 7-11 show the industrial R-lenses in 'RI – ROE' coordinates obtained from the simulation results.

Fig. 7. R lens for industry C11



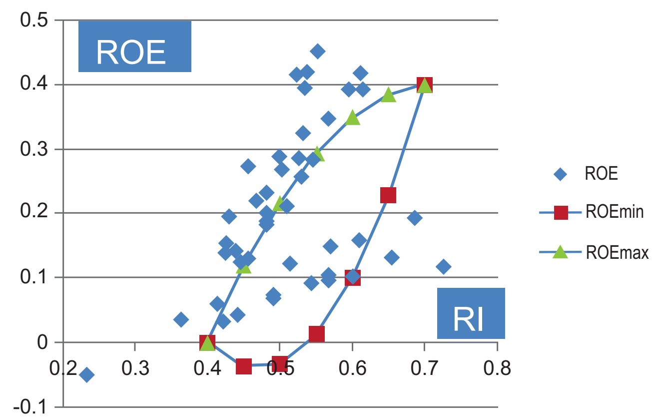
Source: compiled by the authors.

Fig. 8. R lens for industry DJ27



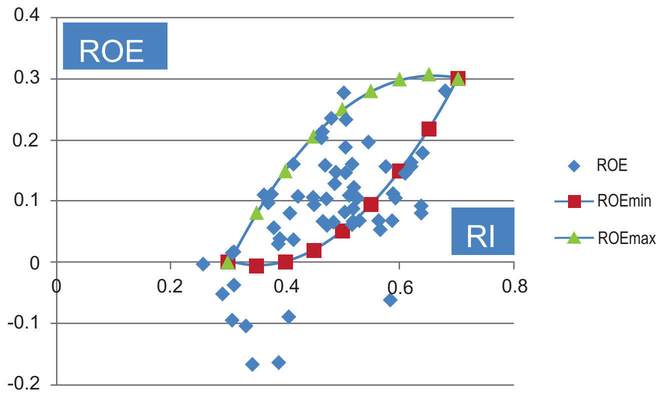
Source: compiled by the authors.

Fig. 9. R lens for industry DK29



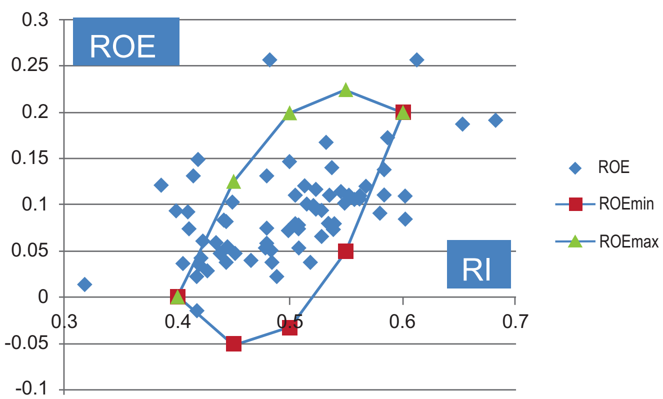
Source: compiled by the authors.

Fig. 10. R lens for industry DL31



Source: compiled by the authors.

Fig. 11. R lens for industry E40



Source: compiled by the authors.

It can be seen that the lenses in Figures 7-11 have varying degrees of occupancy. The less crowded the lens, the more confident we can be about the loss of sustainability of the industry, in a positive or negative sense. The industry is either configuring a new market niche for itself (positive impact), or it is exposed to negative external impacts and is trying to reduce all kinds of risks.

2.2. Stability management in the 'Risk – ROE' coordinates

Let's look at the activities of General Electric (ticker GE) for the period 2015-2022. Tables 6 and 7 summarise the factors of interest to us in terms of sustainability management. It is clear that the company is in deep decline and all its key characteristics are 'dislocated'. The proposed mitigation measures are as follows:

- partial nationalisation of the company with transfer of surplus assets to the state (together with corresponding debts) in the regime of reverse mortgage of real estate;
- reorganisation of the company with regulation of income and expenses to the level of NPR = 5%.

Table 6
GE financials ($ bln)

Year	Revenue (R)	Net Profit (NPR)	Equity Capital (EC)	Balance sheet assets (A)
2015	115.8	–6.1	98.3	493.1
2016	119.5	7.5	75.8	365.2
2017	118.2	–8.5	56.0	369.2
2018	121.6	–22.3	31.0	309.1
2019	95.2	–5.0	29.9	266.1
2020	79.6	5.7	35.6	253.5
2021	74.2	–6.8	41.6	198.9
2022	58.1	–0.1	37.6	188.0

Source: compiled by the authors.

Table 7
Fuzzy numbers and risks for GE

Indicator	min	av	max	Norm	Risk
NPR	–0.183	–0.040	0.072	0.050	0.991
LR	0.235	0.329	0.393	1.500	1.000
FL	3.818	5.525	8.971	1.600	0.000
ROE	–0.719	–0.126	0.160	0.200	1.000

Source: compiled by the authors.

We will design the company for the expected indicators of the forecast year, based on the minimum allowable turnover. Turnover = USD 60 billion. To achieve the required turnover LR = 1.5 times a year, the company's assets must be A = 40 billion dollars. Accordingly, the government needs to transfer about $150 billion of assets, which are then immediately returned to long-term lease (and thus neatly removed from the balance sheet). To ensure a leverage ratio of 1.6, it is necessary to set EC = USD 15 billion, Borrowed Capital (BC) = A - EC = USD 25 billion. Accordingly, the assets transferred to the government for USD 25 billion are backed by equity (expected to be sold) and the remaining USD 125 billion by debt (expected to be transferred from private to public).

If the recommended projects are implemented, the company will move to an investment-attractive ROE level of 20% per annum, and the risks of unprofitability will be reduced to zero. It is absolutely clear that the company's management will never take the proposed measures under normal conditions. It is necessary for another negative wave to hit the market ('the roast rooster has pecked'), and then the option of partial nationalisation will not seem so incredible. After all, it was the path of nationalisation that the insurance company AIG took in 2008 as a result of the global mortgage crisis.

2.3. Stability management in 'Opportunity – ROE' coordinates

Throughout its history, GE has been driven by innovation. One of its founding fathers, Jack Welch, recounts in [Welch, Byrne, 2006] how he revived the company's finance division and turned it into a profitable business in its own right. Today, GE's survival is directly linked to its entry into new market niches, such as artificial intelligence in electrical engineering. The use of neural networks in the design of new high-voltage equipment and networks could be a promising new business for the company with an extremely high return on investment.

Let's assume that EC1 = USD 2 billion of equity and BC1 = USD 3 billion of debt are invested in a new business with revenue expectations of R1 = USD 10 billion. We set vague expectations for marginal, operating and net profitability, typical of blue ocean conditions in the IT industry (Table 8).

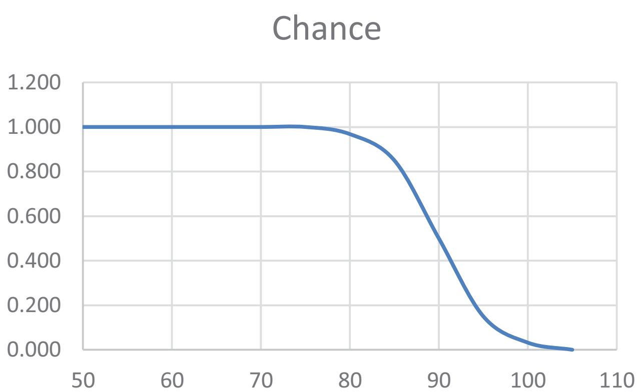
Table 8
Expected profitability for GE's innovation business (%)

Profitability	min	av	max
Marginal profitability (MPR)	50	60	70
Operational profitability (OPR)	25	30	35
Net profitability (NPR)	15	18	21

Source: compiled by the authors.

If, according to the conditions of the problem, LR = 2 times a year and FL = 1.5, we obtain a triangular expectation for ROE = (75%, 90%, 105%) per annum. Let's construct a probability function whose argument is the standard value of ROE from 50 to 100% per annum (Fig. 12). It is clear that as the requirements for the coming ROE level become more stringent, the chances of an innovative breakthrough fall from 1 to 0.

Fig. 12. Opportunity for an innovative project



Source: compiled by the authors.

3. Research findings and discussion

The choice of coordinate space for analysing the sustainability of companies and industries is primarily determined by the intentions of the decision-maker. The first step is to consider the industry lens and the position of the company relative to that lens. If the trajectory of the dynamics of the point representing the company is within the lens, then stability is assured and no special additional solutions need to be taken. If stability is lost, then you need to understand what caused the loss of stability and in what sense (positive or negative) this event should be considered.

In the vast majority of cases, the loss of stability is negative. If the dot is below the lens, the business lacks profitability and it comes down to the ratio of costs to revenues. If the dot is above the lens, the first thing to look at is the size of your net assets. Outliers in ROE are often caused by inadequate EC: either it is continually being washed away by losses, or it is being inappropriately divested by the owners. In both cases, EC needs to be brought to a rational level (the dot needs to return to the lens).

When a company decides to enter new markets with a new innovative product, such a decision is obviously of a random nature. It is necessary to model this decision in 'Chance – ROE' coordinates (in the spirit of Fig. 6) and compare decisions with rational expectations for ROE within the newly outlined segment. We also need to take into account that innovations are quickly copied and the corresponding blue oceans in the Kim-Mauborgne sense collapse. Therefore, random activities should not be the nature of individual actions from time to time, but should be carried out permanently.

All the modelling experience we have accumulated leads to the conclusion that the fuzzy-probabilistic descriptions we use here are an incredibly powerful descriptive platform. This makes it easy to move beyond the boundaries of the company or industry itself and start modelling the impacts themselves, treating them in the model as independent systems with their own structure and deployment logic.

Conclusion

The article presents a wide range of techniques for analysing the sustainability of companies and industries, including taking into account the level of integral risks and opportunities. Quantitative examples show that anti-risk solutions lead to an increase in the sustainability of companies and industries, but at the same time can reduce the company's chances of breakthrough. On the contrary, increasing opportunities across the company automatically leads to a decrease in sustainability; every time capital is diverted to innovation, it means a temporary loss of stability in the name of securing the company's future.

Companies and industries (under government control) must constantly manoeuvre in the coordinate space of 'efficiency - risk – opportunity', choosing acceptable strategies for increasing or decreasing sustainability. In many ways, strategic decisions are influenced by regulatory parametric constraints of an industry nature. For example, in the context of the global economic crisis, a leverage ratio of FL = 3 is tantamount to a catastrophe; the risks of bankruptcy for such a company (especially in view of the FRS turnaround) are off the charts. This means that decisions taken must have a reliable methodological justification. We hope that our work has laid another brick in this foundation.

References

Abdoulaeva Z.I., Nedosekin A.O. (2017). *Industrial and economic risk assessment of enterprises.* St. Petersburg, Publishing House of Peter the Great St. Petersburg Polytechnic University, 2017. (In Russ.)

Kim W.C., Mauborgne R. (2015). *Blue ocean strategy. How to find or create a market free from competitor.* Trans. from Eng. by I. Yushchenko. Moscow, Mann, Ivanov and Ferber. (In Russ.)

Kozlovsky A.N., Nedosekin A.O., Abdulayeva Z.I. (2016). *Management of a portfolio of industrial innovations.* St. Petersburg, Publishing House of Peter the Great St. Petersburg Polytechnic University. (In Russ.)

Malyukov Y.A., Nedosekin A.O., Abdulayeva Z.I. (2023a). *Assessment of economic sustainability of public industrial companies.* St. Petersburg, Publishing House of Peter the Great St. Petersburg Polytechnic University. (In Russ.)

Malyukov Y.A., Nedosekin A.O., Abdulayeva Z.I. (2023b). Application of the 4x6 matrix model for analysis of industry sustainability. *Soft Measurements and Computing,* 6(67): 47-58. (In Russ.)

Malyukov Y.A., Nedosekin A.O., Abdulayeva Z.I., Silakov A.V. (2023c). *Assessment and enhancement of economic sustainability of an industrial enterprise using a balanced scorecard.* St. Petersburg, Publishing House of Peter the Great St. Petersburg Polytechnic University. (In Russ.)

Nedosekin A.O., Malyukov Y.A., Abdulayeva Z.I. (2023). Formation of industry sustainability indices in the fuzzy-logical paradigm. In: *Modern issues of sustainable development of society in the era of transformational processes:* Proceedings of the IX International Scientific and Practical Conference, Moscow, May 19, 2023. Moscow, Alef, 258-263. DOI 10.34755/IROK.2023.63.14.025. (In Russ.)

Welch J., Byrne J. (2006). *My years at GE.* Moscow, Mann, Ivanov and Ferber. (In Russ.)

Buheji M. (2018). *Understanding the power of resilience economy: An inter-disciplinary perspective to change the world attitude to socio-economic crisis.* UK, AuthorHouse. ISBN-10 1546286675.

De Graaf T., Reggiani A., Nijkamp P. (2000). Resilience: An evolutionary approach to spatial economic systems. *Networks and Spatial Economics,* 2: 211-229.

Gunderson L., Pritchard L. (2002). *Resilience and the behavior of large scale system.* Washington, DC, Island Press.

Hill E.W., Wial H., Wolman H. (2008). Exploring regional economic resilience. *Institute of Urban and Regional Development, University of California,* Working Paper. https://escholarship.org/uc/item/7fq4n2cv.

Holling C.S. (1973). Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics,* 4: 1-23.

Holling C.S. (1996). Engineering resilience versus ecological resilience. In: Schulze P. (ed.). *Engineering within ecological constraints.* Washington, DC, National Academy Press.

Hosseini S., Barker K., Ramirez-Marquez J.E. (2016). A review of definitions and measures of system resilience. Reliability *Engineering & System Safety,* 145: 47-61.

Kozlovsky A.N., Nedosekin A.O., Abdoulaeva Z.I., Reyshakhrit E.I. (2020). R-Lenses as a tool for the enterprise resilience analysis. In: *Proceedings of the 2nd International Scientific and Practical Conference "Modern management trends and the digital economy: From Regional development to global economic growth" (MTDE 2020).* https://www.atlantis-press.com/proceedings/mtde-20/125939875.

Martin R. (2011). Regional economic resilience, hysteresis and recessionary shocks. *Journal of Economic Geography,* 12: 1-32.

Martin R., Sunley P. (2013). On the notion of regional economic resilience: Conceptualization and explanation. *Papers in Evolutionary Economic Geography,* 13.20: 1-45.

Muller G., Koslowski T., Accorsi R. (2013). Resilience - A new research field in business information systems? In: Abramowicz W. (ed.). *Business information systems workshops, Lecture notes in business information processing,* 160: 3-14. Berlin, Heidelberg, Springer.

Nedosekin A., Abdoulaeva Z., Konnikov E., Zhuk A. (2020). Fuzzy set models for economic resilience estimation. *Mathematics,* 8(9): 1516.

Perrings C. (2006). Resilience and sustainable development. *Environment and Development Economics,* 11(4): 417-427.

Sabatino M. (2019). Economic resilience and social capital of the Italian region. *International Review of Economics & Finance,* 61. DOI: 10.1016/j.iref.2019.02.011.

Walker B.H., Gunderson L.H., Kinzig A.P., Folke C., Carpenter S.R., Schultz L. (2006). A handful of heuristics and some propositions for understanding resilience in social-ecological systems. *Ecology and Society,* 11(1): 13. http://www.ecologyandsociety.org/vol11/iss1/art13/.

About the authors

Yury A. Malyukov
Candidate of engineering sciences, vice-rector for Economic Development and Informatization, The Kosygin State University of Russia (Technology. Design. Art) (Moscow, Russia). ORCID: 0009-0006-6299-4938.
Research interests: innovation in the field of light industry enterprises, fuzzy logic in economics, enterprise resilience, engineering.
riemtk@rguk.ru

Alexey O. Nedosekin
Doctor of economics, candidate of engineering sciences, academician of IAELPS, CEO of LLC "Institute of Financial Technologies" (Saint Petersburg, Russia). ORCID: 0000-0003-3882-8236.
Research interests: fuzzy logic in economics and finance, business resilience, corporate governance, financial management.
sedok@mail.ru

Zinaida I. Abdoulaeva
Candidate of economic sciences, associate professor of the Department of Medical Informatics and Physics, North-Western State Medical University named after I.I. Mechnikov (Saint Petersburg, Russia). ORCID: 0000-0001-7093-785X.
Research interests: fuzzy logic in economics, business resilience, corporate risks, digitization, engineering.
zina@bk.ru

作者信息

Yury A. Malyukov
技术科学副博士，俄罗斯国立A. H. 柯西金大学（技术。设计。艺术）经济发展与信息化副校长（俄罗斯莫斯科）。ORCID：0009-0006-6299-4938.
研究领域：轻工业企业领域的创新、经济模糊逻辑、企业可持续性、工程学。
riemtk@rguk.ru

Alexey O. Nedosekin
经济学博士，技术科学副博士，国际生态、人类安全和自然科学学院院士，“金融技术研究所”有限责任公司总经理（俄罗斯圣彼得堡）。ORCID：0000-0003-3882-8236.
研究领域：经济和金融模糊逻辑、企业可持续性、公司治理、财务管理。
sedok@mail.ru

Zinaida I. Abdoulaeva
经济学副博士，以梅契尼科夫名字命名的西北国立医科大学医学信息学和物理学系副教授（俄罗斯圣彼得堡）。ORCID：0000-0001-7093-785X.
研究领域：经济模糊逻辑、企业可持续性、企业风险、数字化、工程学。zina@bk.ru

The article was submitted on 28.05.2023; revised on 16.06.2023 and accepted for publication on 25.06.2023. The authors read and approved the final version of the manuscript.
文章于 28.05.2023 提交给编辑。文章于 16.06.2023 已审稿. 之后于 25.06.2023 接受发表。作者已经阅读并批准了手稿的最终版本。