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Key indicators of innovation performance: Perception of significance and practical application

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Abstract

This paper is devoted to the study of the correlation between the perceived significance of indicators of innovation activity and their actual use at enterprises of the Russian manufacturing industry. A sample of 132 manufacturing enterprises in Russia was used for the analysis. It was found that the recognition of the significance and the actual use of financial and non-financial indicators varies significantly depending on the affiliation of companies to a particular innovation regime: radical innovators, technological innovators, effective producers, creators of value innovations and imitators. Three key performance indicators (KPIs) reflecting the company's focus on the introduction of technological innovations (the share of modern equipment in the company's technology park (taking into account the technological features of industries); the average time to adapt the acquired innovative product, days; the share of implemented patents from the total number of patents received by the organization) were recognized as important managers of companies belonging to technological and radical innovators (74.5, 76.9, 78.1%, respectively). Three key performance indicators reflecting customer orientation (the number of new categories of products or services introduced in the reporting year; the share of products certified according to international standards in the total production of the company; the percentage of innovative expenditures on the modernization of existing products/processes/business models in relation to the total innovative expenditures on products/processes/business models) were recognized as important companies classified as effective producers and creators of value innovations (83.4, 81.9, 76.8%, respectively).

But at the same time, the study showed that the most commonly used indicators are sales growth from new products (88.7%); the share of patents implemented (74.3%); total R&D expenses per 1 thousand dollars of revenue in the current reporting period (89.2%). In summary, conclusions are drawn about the actual application of key performance indicators of innovation activity by companies.

Keywords: innovation, metrics of innovation activity, key performance indicators, level of innovation activity, industrial company, effectiveness of innovation activity.

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Introduction

The introduction of innovations as a source of competitiveness between industrial companies contributes to the fact that the issues of assessing the effectiveness of innovative activities attract more and more attention among researchers and experts [Klein et al., 2001; Glassman, 2009; Trachuk, Tarasov, 2015]. At the same time, a number of specialists consider the effectiveness of innovation activity as one of the most significant [Dennis, 2003; Morris, 2008; Glassman, 2009].

It should be noted that despite a fairly developed classification of innovation metrics, they were all developed by foreign researchers, and the possibility of their application in the practice of Russian industrial companies has not been sufficiently studied. There are no empirical studies which analyze the use of metrics by Russian industrial companies. An overview of the existing classifications related to innovation performance metrics is given by the authors in the articles [Trachuk, Linder, 2016; 2019; Trachuk and Linder, 2019].

The studies of foreign authors on the use of key performance indicators show that investments in innovative technologies, such as lean manufacturing, customer relationship management (CRM), enterprise resource planning (ERP) and rapid prototyping cannot successfully complete the implementation stage and evaluate improvements [Dennis, 2003] as efforts on implementation must be monitored and diagnosed [Shiba et al., 1993].

In addition, evaluating the effectiveness of innovations provides an opportunity to identify problems and weaknesses and to take corrective action before these problems escalate [Kueng, 2000].

The purpose of this study is to analyze the perception and actual application of key performance indicators of innovative activities by industrial companies.

The choice of industry is explained by several reasons. First, it is industrial companies that have the largest investments in innovation. Secondly, during an economic downturn and limited access to financial capital, industrial companies will assess the effectiveness of investment in innovation more closely. Thirdly, due to the peculiarities of the industrial sector, justifying the costs of innovation activities through the introduction of key performance indicators is one of the highest priority tasks.

To achieve this goal, a task was set based on the classification of innovations and innovative metrics existing in the academic literature, which were described by the authors earlier [Trachuk, Linder, 2019;], to study which of them are recognized by practitioners as the most significant and which of them are most often used in practice. As part of the empirical approach, in-depth interviews and questionnaires with representatives of the top management of Russian industrial companies were conducted.

1. Theoretical review and formulation of research hypotheses

In academic research, there are several areas for assessing the effectiveness of innovation.

The earliest one was performance evaluation based on financial indicators such as return on investment [Norman, Bahiri, 1972; Barbosa, 2004]. However, later this approach was criticized, since, according to researchers, it does not provide feedback on the effectiveness of internal business processes and the contribution of employees to achieving this efficiency [Kaplan, Norton, 1992; Abdel-Maksound, 2004].

Therefore, in the future, researchers began to offer indicators that measure the innovation process and innovative activity of companies, for example [Morris, 2008].

However, no single performance indicator can capture the full complexity of innovation activity [Amaratunga et al., 2001]. To be successful in today's globally competitive environment, organizations must be able to capture objective (e.g. unit costs, profit) and subjective (e.g. quality, satisfaction) measures. Therefore, researchers began to propose models that allow for the evaluation of innovative activity in a complex way [Coombs et al., 1996; Verhaeghe and Kfir, 2002; Gupta, 2007; Ortiz et al., 2007].

Other researchers began to use econometric modeling to analyze the relationship between innovation and company performance [Lööf, Heshmati, 2002; Mairesse and Mohnen, 2004].

A number of other authors have proposed the use of multidimensional indicators [Salomo et al., 2008; Good, Tellis, 2009; Choi, Ko, 2010], as well as to investigate the effectiveness of balancing financial and non-financial indicators in the performance evaluation system [Kerssens van Drongelen, Bilderbeek, 1999; Hudson et al., 2001; Kanji and Sa', 2002; Savioz, Blum, 2002; Bremser and Barsky, 2004].

In addition, some studies have emerged that focus on the use of financial and non-financial indicators by companies and assessment of their perceived importance. The results of such studies have led to the conclusion that there is a direct relationship between a company's assessment of the perceived significance of an indicator and its actual use, for example [Kaplan, Norton, 1993; Cox et al., 2003].

A variety of approaches to measuring the effectiveness of innovation activity is presented in Table 1.

Thus, the considered approaches can be divided into the following groups depending on their focus:

1) related to the innovation process;

2) indicators grouped in a balanced scorecard;

3) other approaches, for example in relation to the innovation climate or the ability to innovate.

Models of the first group use the idea of measuring the "input – process – output" of innovation activity [Goffin, Mitchell, 2010; Tidd and Bessant, 2014]. Some authors, in particular [Möller et al., 2011], propose to separate the concepts of "output" as a short-term effect and "result" as a long-term effect, as well as the system for obtaining the result (for example, marketing and sales efforts) and the result itself [Vahs and Brem, 2015]. Thus, the Input – Process – Output – Outcome (IPOO) model uses specific indicators for each stage of the company's innovation process, such as the training cost of one employee at the entry stage and the number of new products at the exit stage [Fischer et al., 2015].

It should be noted that the use of outcome criteria such as market share gained through innovation, etc., entails two distortions:

– firstly, one cannot be sure of obtaining reliable measurement results, since a sufficiently large amount of time can pass between the introduction of an innovation and its positive effect;

– secondly, there is a difficulty in clear distinguishing the effect of innovation from other factors that could lead to a measured increase in a market share.

Along with complex approaches to measuring the innovation process, there are approaches in the research that focus on certain aspects of the process. For example, the R&D Return system [Vahs, Brem, 2015] was created to evaluate performance in R&D only. In this approach, R&D productivity is measured by the potential productivity and efficiency of technology development and compared with the R&D profitability which consists of potential productivity and operational efficiency. In addition, to calculate the value of the return on R&D, a certain algorithm is used that combines all indicators. This system can be transferred to other business units of the organization.

In contrast to these scoring systems, Bean consulting company proposed to simply quantify the innovative output of the R&D department [Pappas, Remer, 1985]: the number of patents, publications, citations, etc. or simply by counting the number of new ideas [Fuchs, 2014].

The second group of approaches includes those based on a balanced scorecard, such as the Innovation Balanced Score Card [Fischer et al., 2015]. The four dimensions of a typical balanced scorecard (finance, customers, internal business processes, learning, and growth [Kaplan, Norton, 1992]) are assessed with the help of a company's innovation strategy with a focus on improving the effectiveness of innovation, such as time to market for a new product, market share obtained through R&D [Žižlavský, 2016].

Another assessment method is innovation audits. When conducting an innovation audit, not only the results of innovative activities (output indicator) are considered, but also how these results were achieved (process indicator). For this, aspects such as innovation strategy, market, product, technology, etc. are evaluated. [Goffin, Mitchell, 2010]. Examples of such indicators for the "market" aspects are: change in market share thanks to new products, number of customer surveys, number of implemented innovations based on customer ideas, etc. [Warschat, 2005] or 5 measurements of A.T. Kearney "House of Innovation" or Improve [Innovety, 2014].

The group of other approaches is diverse. They usually have a specific focus, such as INNO assessing the innovation climate [Kauffeld et al., 2004] or describing general determinants of innovation ability [Jong et al., 2001]. Some of the used criteria intersect with other approaches, some are specially adapted to a specific task (for example, export activity) [Jong et al., 2001].

Thus, there is a wide variety of metrics to measure innovation in companies or business units. They vary widely in complexity and data requirements involving effort to collect and analyze data. In choosing the right approach for a particular situation, the differentiating criterion should probably be the availability of the resources necessary to collect and analyze the data.

Separately, it is possible to single out the indicators used for the operational control of innovation activity focused on the indicators for the implementation of innovative projects [Fischer et al., 2015].

Similar to the due diligence method, indicators of typical project control are proposed, such as control of project stages or budget [Maier et al., 2007; Vahs and Brem, 2015]. In other studies, the effectiveness of innovative projects is measured by the duration of a new product development and its costs [Fuchs, 2014] or the return on investment of innovative projects [Hauschildt, Salomo, 2007]. In addition, some studies argue that the only way to assess innovation activity is to evaluate the progress of these innovation projects [Littkemann, Derfuß, 2011]. However, this argument ignores the fact that innovation in a company is not always associated with projects, but the whole company including project activities, teamwork, should strive to be innovative [Fischer et al., 2015]. Thus, in addition to measuring the effectiveness of innovative project implementation, indicators are necessary to evaluate the achievements of innovative teams.

The purpose of this study is to analyze which of innovation efficiency indicators are used by Russian

Table 1
Approaches to measuring the effectiveness of innovation in organizations

Author / model name	Analysis level	Indicator type	Used indicators	Reference
Input-Process-Output-Revenue Model (IPOO)	Company	Financial and non-financial	For example, [Möller et al., 2011]: *Entrance:* *quantitative:* the cost of R&D, the number of ideas, the cost of training of one employee; *quality:* employee experience, quality of ideas *Process:* *quantitative:* working hours on the project, the number of results achieved in time; *qualitative:* product/service quality, progress *Exit:* *quantitative:* number of patents, number of new products, average cost per patent *qualitative:* synergetic effect, results of fundamental research; *Income:* *quantitative:* increase in sales/profits, cost reduction; *quality:* product improvement, customer satisfaction	A similar approach to measurement is also supported by other authors, for example [Fischer et al., 2015; Vahs, Brem, 2015]
Balanced Scorecard for Innovation	Company	Financial and non-financial	Example of balanced scorecard with an emphasis on improving the efficiency of innovation [Fischer et al., 2015]: Sales of new products in relation to required investments, time to entry the market for a new product Market share gained through R&D	The approach describes the implementation of a balanced scorecard with a particular focus on innovation success.
Innovation Audit Scorecard (InnoAudit-Scorecard)	Company	Financial and non-financial	Innovation audit considers not only the results of innovation activities (outcome indicator), but also how these results were achieved (process indicator) [Goffin, Mitchell, 2010. P. 317). Indicators are defined for various aspects, such as market, project management, product, innovation culture, know-how, etc. [Warschat, 2005]	InnoAudit-Scorecard is a tool for self-diagnosing of companies and identifying the potential for improving the efficiency of innovation in each particular company [Warschat, 2005. P. 13]
[Goffin, Mitchel, 2010]	Company	Financial and non-financial	The metrics of this approach are similar to the quantitative metrics of the IPOO model. IPOO inputs and outputs constitute Goffin's "aspect outcome" [Goffin, Mitchell, 2010. P. 316]	
Improvement	Company	Financial and non-financial	The indicators are grouped into 5 areas: innovation strategy, innovation culture, innovation life cycle processes, enabling factors and outcomes of innovation. Examples of indicators are - time to market for a new product / profit, customer feedback, management of the flow of innovations and ideas, ability to innovate, etc. [Innovety, 2014. P. 5]	Measuring the effectiveness of a company's innovation process with the Improve tool is based on A.T. Kearney [Innovety, 2014. P. 5]
[De Jong et al., 2001]	Company	Financial and non-financial	The model includes 50 determinants, which are grouped into 9 categories: personnel characteristics, innovation strategy, innovation culture, structure, availability of financial resources, network activities, company characteristics, innovation infrastructure and market characteristics [De Jong et al., 2001. P. 9- ten]	The model describes the determinants of an organization's innovative capabilities. [De Jong et al., 2001. P. 9]

Table 1 *(ending)*

Author / model name	Analysis level	Indicator type	Used indicators	Reference
Innovation statistics (surveys) (e.g. CIS Finland, ZEW Germany)	Company	Financial and non-financial	Examples of observed indicators [Rammer et al, 2016]: Number of product innovations/process innovations, innovation activity in the last 3 years, number of new products, surveys regarding innovation barriers, etc.	Typically, these data are used to measure innovation performance in addition to more traditional measures such as patents. [Leiponen, Helfat, 2006. P. 9]
[Michie, Sheehan, 2003]	Company	Non-financial	Firms were asked the following questions: "Over the past three years, how many product innovations has the company introduced?" and "In the last three years, how many process innovations has the company introduced?" [Michie, Sheehan, 2003. P. 129]	
Bean counting	Business unit	Non-financial	Examples of indicators: number of patents, publications, citations, etc. [Pappas, Remer, 1985]	The goal is to quantify the productivity of R&D personnel [Pappas, Remer, 1985. P. 18]
(R&D Return Framework)	Business unit	Financial	The indicators of the system for assessing the profitability of R&D are [Vahs, Brem, 2015. P. 648]: R&D productivity - the potential productivity and efficiency of technology development R&D profitability - potential profitability and operational efficiency	With this approach, the overall value of the efficiency of the R&D department is calculated
INNO	Business unit	Non-financial	The INNO assessment tool consists of 21 items divided into four groups of factors: (1) innovative leadership, (2) constant questioning, (3) consistent implementation, and (4) professional documentation [Kauffeld et al., 2004. P. 155]	ITCI is "a measure of the group climate in organizations and is used in team building and organizational development" [Anderson et al., 2014. P. 255]
Team Climate Indicator	Business unit (department)	Non-financial	The TCI indicator measures 38 questions [Anderson et al., 2014. P. 246] regarding team goals, friendliness of team members, ability to come up with new ideas, assessments of weaknesses, evaluation of work, ways to solve problems, etc.	TCI является «мерой группового климата в организациях и применяется при формировании команды и развитии организации» [Anderson et al., 2014. P. 255]
Complex assessment method	Project	Non-financial	Indicators for evaluating technology, technological progress compared to existing products, as well as leadership in R&D, availability of necessary know-how, etc.	Technological aspects and market prospects of an innovative product are assessed with the help of expert interviews and panels [Vahs, Brem, 2015. P. 346]
Fuchs	Project	Non-financial	Innovative efficiency should be measured by the duration of the development of a new product, the costs of developing a new product, the assessment of the level of novelty compared to the average market turnover / profit achieved [Fuchs, 2014. P. 31]	Based on the results from individual projects, the company's innovative activity is analyzed [Fuchs, 2014. P. 31]

The source: compiled by the authors.

industrial companies, which of them are perceived by management as significant, and whether the use of the indicator depends on the recognition of its significance for the success of innovation. In addition, it is interesting to answer the question how much the implementation of an innovation strategy and the company's adherence to one or another type of innovative behavior will affect the perceived significance of indicators for assessing the effectiveness of innovative activity and their use.

The hypotheses of this study are:

H1. The perceived importance of KPIs will differ depending on the type of innovative behavior an industrial enterprise pursues: radical innovators, technological innovators, efficient producers, value-innovators, or imitators.

H2. For technological and radical innovators, non-financial performance indicators of innovation activity will be the most significant, and for creators of value innovations, efficient producers and imitators, financial performance indicators of innovation activity will play a great role.

H3. For companies of all innovation regimes, there will be a positive relationship between the perceived importance of the indicator and its actual use in innovation performance assessing.

2. Methodology of the study and description of the sample

Since the design of an exploratory study was chosen to achieve the goal of the work, in-depth interviews became the main method of collecting information at the first stage. At the second stage, a survey of top management representatives of industrial companies was used. The methodology of the first and second stages of the study is presented in Table 2.

Since the design of the study involves the participation of one to five employees from each company, a total of 37 respondents were interviewed – heads of departments involved in innovation activities (in particular, respondents held the positions of heads of R&D departments, heads of research institutes, strategic planning departments, etc.),

Table 2
Description of the stages of empirical research

	Stage 1	Stage 2
Stage goal	To identify metrics that industrial companies consider important when evaluating their innovation performance	To identify the features of innovative metrics' application by Russian industrial companies
Research question	What metrics of company's innovation activity are considered the most important for evaluating the effectiveness? What are the relationships between quantitative and qualitative metrics?	What innovation metrics do industrial companies use? Who in the company is responsible for evaluating innovation activities? What is the process of evaluating innovation activities? Does the company develop its own metrics to measure innovation performance?
Data collecting method	37 in-depth interviews	139 questionaries
Data type	Text-oriented	Text-oriented
Data processing method	Content analysis, emic authenticity method	Standard methods of psychometric research that are used in the conduct of questionnaires, reliability factor analysis (Cronbach's Alpha)
Instruments of the analysis	Microsoft Excel	Microsoft Excel

The source: compiled by the authors.

Table 3
Characteristics of types of innovative behavior

Characteristics	Effective producers	Technological innovators	Creators of value innovation	Radical innovators	Immitators
1	2	3	4	5	6
Intensity of investment in research and development (R&D)	1-3% of gross revenue	3-7% of gross revenue	Not provided	15-35% of gross revenue	Not provided
Types of implemented innovations	Product and process innovations	Product and process innovations	Marketing and organizational innovations	Value innovations	Managerial innovations
The level of novelty of implemented innovations	New to the local market, new to the company	New to the local market	New to the local market, new to the company	New for the world	Pseudo innovations
Building a corporate innovation system (CIS) and the presence of intercompany relationships in the innovation process	CIS of a closed type, focused on the creation of new products due to the integration of technologies with partners	Built on the principle of "open innovation"	The construction of an innovation system and the features of the innovation process are determined by the presence of untapped markets and niches	Built on the principle of "open innovation", that is, there is an extensive network of partnerships	Of closed type or absent
Cost structure for innovation activities	Maximum investment in technology upgrades and infrastructure improvements while minimizing marketing innovation costs	Maximum investment in product innovation	High costs for marketing innovations, then - organizational and managerial. The costs of product and process innovations in most cases have a small share or they are absent.	Development and implementation of new products based on the commercialization of fundamental scientific research	Staff training costs
Own R&D department	Yes	No	No	Yes	No

The source: [Linder, 2020].

Table 4
Distribution of industrial enterprises by type of innovative behavior

Innovative mode	Radical mode	Technological innovator	Effective producer	Creator of value innovations	Imitator
Number and share of industrial enterprises	15 (11%)	26 (18.5%)	44 (31.7%)	30 (21.3%)	24 (17.5%)

The source: compiled by the authors.

Table 5
Characteristics of sample companies

	All companies	Radical innovator	Technological innovator	Effective producer	Creator of value innovations	Imitator
Number of companies	139	15	26	44	30	24
Share of companies in the sample implementing product innovations	0.92	0.91	0.85	0.317	0.63	0.75
Share of companies in the sample implementing process innovations	0.87	0.83	0.92	0.99	0.74	0.66
Total costs for technological, marketing and organizational innovations (million rubles)	100959400	42064000	28092000	17006000	7845300	5952100
Including R&D expenses (million rubles)	29278100	17354600	7318000	4605500	2741831	1611925
Average R&D expenses (million rubles)	50306	103919	29389	27743	12347	17163.54
Median of real expenditure on R&D (million rubles)	2675	4011	2320	1044	927	784

The source: compiled by the authors.

Table 6
Innovation metrics used by industrial companies

Groups of metrics	Metrics	Frequency of metrics' mentioning (%)
Focus on technological innovations	Percentage of rejected patents Percentage of patents for sale Average number of prototypes per new product Percentage of new patents in a key research area Average lead time for patent applications The average time between the emergence of an idea and the receipt of a patent Average cost of a patent	79
Level of innovation activity	Total number of investments in non-key innovative projects New product development costs Percentage spent on developing of new products and services Percentage of investments in non-key innovative projects Percentage of resources dedicated to groundbreaking innovations Percentage of invested capital	84
Key role of CEO	Availability of breakthrough projects in IDP Number of technologies being designed and proposed for use Number of patents and other intangible assets put on the balance sheet based on the results of R&D Number of technologies and products developed and introduced into production based on the results of R&D performed	38
Economic effect	Growth in labor productivity (%) Cost reduction from technology implementation (%) The structure of expenditures on R&D Share of R&D expenses in revenue (%) R&D expenses in the reporting year (million rubles) R&D expenses per 1 employee in the current reporting period (rubles) Growth rate of R&D spending compared to the previous three years (%) Share of R&D spending on the development of fundamentally new technologies/products (%) The share of R&D costs that gave positive results in the total amount of R&D costs completed in the reporting period, % Share of R&D spending on non-key innovation projects (%) Share of R&D spending on upgrading existing technologies/products (%) Average cost of a patent (million rubles) R&D costs to the number of patents received (million rubles)	97
Qualified personnel and staff training	Number of tools and methodologies aimed at stimulating innovative activity among employees engaged in innovative work Number of new ideas Average time to develop a new product Number of personnel employed in the field of innovation Number of proposals for the creation of new technologies, technical and technological solutions received from subsidiaries and organizations in the accounting year	71
Commercialization	Share of products and services developed and put into production over the past 5 years The share of products certified according to international standards in the total volume	94
Intercompany cooperation	Availability of joint research programs with universities, programs to improve the quality of education and training Availability of students, graduate students and scientific and teaching staff of universities undertaking internships in the company Participation of the company in technological forecasting and activities of technology platforms The volume of joint research work with universities Development of innovative interaction with small and medium-sized businesses	47
Customer-oriented approach	Percentage of innovation spending on new product/process/business model categories relative to total innovation spending on products/processes/business models Percentage of innovation spending on expanding existing products/processes/business models relative to total innovation spending on products/processes/business models Percentage of innovation spending on upgrading existing products/processes/business models in relation to total innovation spending on products/processes/business models	28

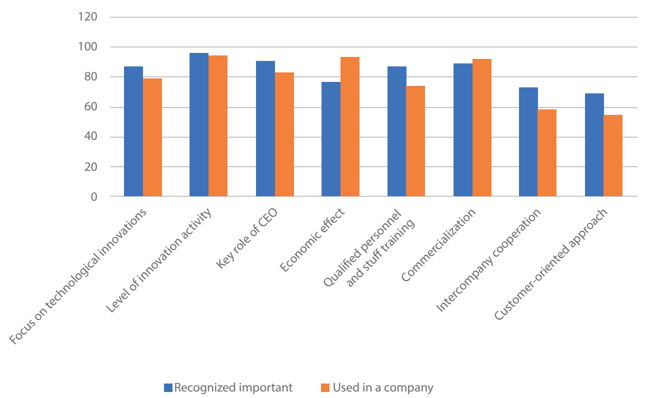
The source: compiled by the authors.

Table 7
Top 3 metrics of innovation activity for industrial companies belonging to different innovation modes

Innovation mode	Radical innovator	Technological innovator	Effective producer	Creator of value innovations	Imitator
Number and share of industrial enterprizes	15 (11%)	26 (18.5%)	44 (31.7%)	30 (21.3%)	24 (17.5%)
Top 3 metrics most important for evaluating innovative performance	• Focus on technological innovation • Level of innovation activity • The key role of the CEO	• Focus on technological innovation • Intercompany interaction • Commercialization	• The key role of the CEO • Focus on technological innovation • Economic effect	• Customer focus • Qualified staff and employee training • Economic effect	• Customer focus • Commercialization • Economic effect

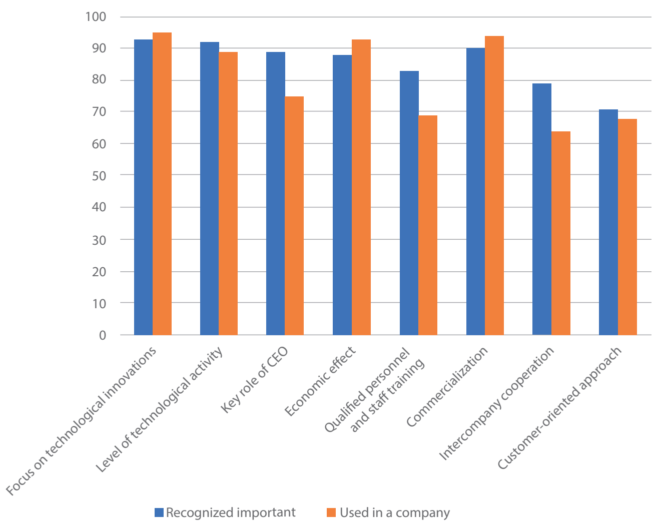
The source: compiled by the authors.

Fig. 1. Importance and use of innovation performance metrics for radical innovators



The source: compiled by the authors.

Fig. 2. Importance and use of innovation performance metrics for technology innovators



The source: compiled by the authors.

as well as deputy top managers for innovation, science and development. Interviews took place from October to November 2021 in person or via videoconference. The duration varied from 30 minutes to 1 hour. The average interview time was 45 minutes.

At the second stage, 589 questionnaires were sent to representatives of Russian industrial companies. Feedback was received from 139 companies, the response accounted for 23.6%. The high response rate is explained by the fact that some of the questionnaires were distributed among students on additional professional education programs from the Faculty of Higher School of Management of the Financial University, where the authors deliver lectures. The survey took place from December to February 2022.

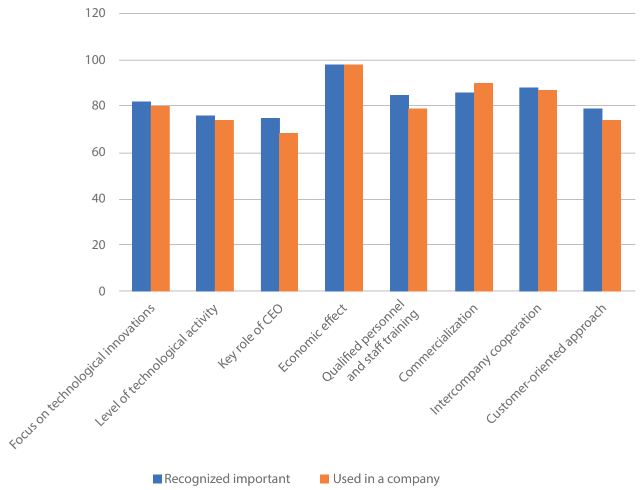
3. Formation of the study sample

When forming the sample, the following criteria for selecting companies were determined. Firstly, the company must belong to the manufacturing industries and operate on the territory of the Russian Federation. Secondly, the company must be engaged in innovative activities, and thirdly, the number of employees of the company must be more than 100.

Since the hypotheses of the study require a breakdown of the set of enterprises according to the type of innovative behavior, then they were further broken down in accordance with the characteristics inherent in a particular type of innovative behavior, described in the article [Linder, 2020] and presented in Table 3.

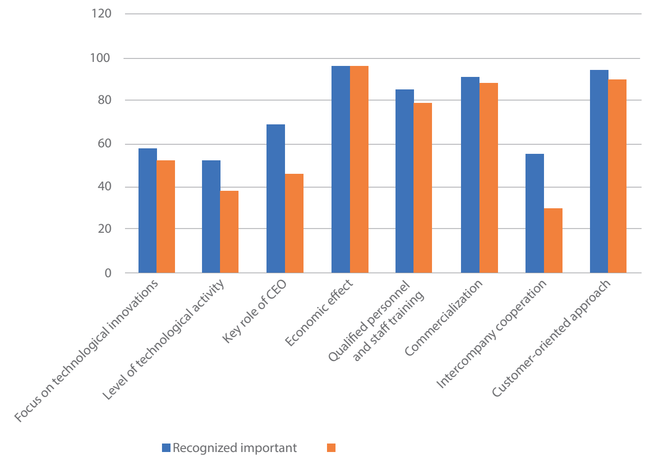
The distribution of companies by the type of innovative behavior is presented in Table 4. The characteristics of the companies included in the sample are presented in Table 5. It should be noted that the R&D expenses of the sample companies are characterized by an extremely wide spread.

Fig. 3. Importance and use of innovation performance metrics for efficient producers



The source: compiled by the authors.

Fig. 4. Importance and use of innovation performance metrics for value innovation creators



The source: compiled by the authors.

4. The results of the empirical study

All in-depth interviews were analyzed with the use of the content analysis method and checked for emic authenticity. As a result, 63 innovative metrics used by Russian industrial companies were identified and divided into 8 groups.

Table 6 presents the obtained results.

As can be seen from Table 6, Russian industrial companies most often use metrics evaluating commercialization (94%), economic effect (97%) and focus on technological innovation (78%) to assess the effectiveness of innovation.

The least frequently used metrics are customer focus (28%), intercompany collaboration (47%) and the key role of the CEO (38%).

However, it should be noted that such a distribution of metrics is not typical for all companies. The importance of certain metrics depends on what type of innovative behavior the company adheres to (Table 7).

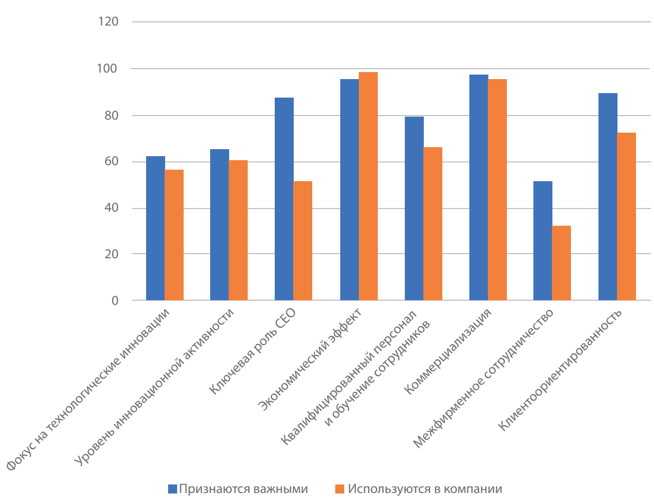
According to the companies belonging to radical and technological innovators innovation activity, on the one hand, should have a positive effect on the results of research and development (patents, prototyping, etc.) and, consequently, on commercialization and economic efficiency, expressed in increasing productivity, cost reduction as a result of the introduction of technologies, etc. On the other hand, it is not so much the economic and financial result that is important, but the overall level of innovation activity: the amount of investment in non-key innovation projects, the level of spending on the development of fundamentally new products and services, etc.

At the same time, for the creators of value-added innovations, customer focus is important in innovative activities, which allows them to commercialize innovations effectively and, consequently, obtain a positive economic effect.

Thus, our first hypothesis is confirmed: indeed, companies that implement different types of innovative behavior consider different groups of performance indicators important for themselves.

To test the second hypothesis, respondents were asked whether they consider these indicators important for their organization, and whether the organization uses them to measure the effectiveness of innovations. Since some

Fig. 5. Importance and use of innovation performance metrics for simulators



The source: compiled by the authors.

Table 8
Top 7 metrics of innovation efficiency used by Russian industrial companies

Innovation metrics	Frequencies of mention (%)				
	Radical innovators	Technological innovators	Effective producers	Creators of value innovations	Simulators
Share of new products in total sales revenue	94	89	83	76	59
Share of revenue from sales of new products	89	91	78	62	53
Margin of new products	61	54	69	81	77
Created objects of intellectual property	65	77	51	7	11
Share of intellectual property objects implemented	68	71	43	3	4
Sold technologies	66	57	39	8	12
Business diversification through innovation	32	41	37	28	25

The source: compiled by the authors.

respondents may report using metrics to measure the effectiveness of innovations whereas they do not actually use them, we applied a methodology designed to reduce the “social desirability” effect. That is, to ensure accuracy in responses, participants were asked to indicate the actual measurement systems used to collect information for each indicator. For example, respondents who reported that they measured the innovation activity level of employees engaged in innovation work should describe a measurement recording system, such as an employee survey, as the tool used to obtain this information. The results are shown in Figures 1–5.

Differences in the recognition of innovation metrics importance and their use in the company were tested by the ANOVA method to identify statistically significant differences. It turned out that the recognition of the importance and use of innovative metrics vary greatly across groups of companies, depending on the economic behavior under implementation.

It was found out that the perceived importance and actual use of innovation metrics are interrelated for companies of all innovation modes: radical innovators – Pearson's – χ^2 (25, 34) = 54.27, $p < 0.001$; technological innovators – Pearson's – χ^2(17, 55) = 67.17, $p < 0.000$; efficient producers – Pearson's – χ^2 (31, 64) = 58.73, $p < 0.000$; создатели ценностных инноваций – χ^2 creators of value innovations – Pearson's (29, 71) = 69.78, $p < 0.000$; imitators – Pearson's – χ^2 (26, 59) = 66.15, $p < 0.000$ respectively.

It was also obtained that the perceived importance and actual use of financial metrics is higher for efficient producers, value innovators, and imitators, while the perceived importance and actual use of non-financial metrics is higher for technology and radical innovators.

Thus, the second hypothesis confirms that for technological and radical innovators the most significant will be non-financial indicators of the innovation effectiveness, and for the creators of value-based innovations, efficient producers and imitators, the most significant will be financial indicators of the innovation effectiveness.

However, the overall results show that 38-40% of technology and radical innovator companies that highly rated the importance of non-financial KPIs (i.e. quality or product/service measures, new product creation time, employee development and knowledge) did not use these key performance indicators to evaluate the effectiveness of innovation activities. Similarly, 21% of value-innovating companies that highly rated customer satisfaction did not use this KPI.

As a result, it should be recognized that there may be some potential barriers between the perception and actual use of both financial and non-financial indicators.

Thus, the third hypothesis was partially confirmed.

5. Discussion of the results of the study

It should be noted that recently industrial companies have been paying a lot of attention to both product and process innovations, which makes it necessary to evaluate the effectiveness of such activities. At the same time, the variety of innovative activities allows companies to calculate not only the main metrics, but also more complex ones.

It is important to note that when distributing metrics into groups, some indicators, depending on the purpose of application, can be attributed to other groups. For example, the metric "Costs for the development of a new product" can be attributed both to the level of innovative activity and to its effectiveness.

Frequency analysis showed that seven metrics are used by more than 50% of companies, the remaining metrics are used by no more than 15% of companies.

In addition, the importance of certain metrics depends on what type of innovative behavior the company adheres to (Table 8).

In most cases, industrial companies use well-studied standard metrics, adapting them in accordance with the goals set in the innovation strategy, that is, in accordance with innovative behavior. At the same time, about 10% of companies use unique, specially designed innovation metrics. Most of these companies belonged to the type of innovative behavior "technological and radical innovator". Also, for companies of these types, non-financial metrics for assessing the effectiveness of innovation activity turned out to be more significant than financial ones. For companies of the other three innovative types of behavior, financial metrics are more significant. Among leading and lagging indicators, the second ones are used to a greater extent, allowing to judge the achievement of goals for a certain period of time.

In most cases, the recognition of a metric as important entails its use to assess the effectiveness of innovative activities. However, this trend is not typical for all indicators.

For example, during the interviews, metrics reflecting collaboration in innovation activities were recognized as important (especially by companies classified as technological innovators and efficient producers), but subsequently they were rarely used to assess the effectiveness of innovation activities.

You can also notice that the more innovative activity is developed in a company, the more unique metrics are used to evaluate its performance.

6. Conclusions and limitations

The study showed that despite the universality of innovation activity metrics they are used in accordance with the objectives of the innovation strategy and the type of innovative behavior of an industrial company. In addition, the study showed the importance of the metric perception by the head of a company, since the majority use those metrics that are perceived by the head as the most significant. More often, financial metrics and lagging metrics are used to assess the achievement of goals over a certain period of time.

Based on the results of this study, it can be assumed that raising the awareness of managers about the balance of financial and non-financial indicators will increase the actual use of these indicators.

Since well-studied standard metrics were used more often, conducting trainings, seminars or discussion panels on the use of innovation performance metrics will allow business leaders to learn more about what kind of metrics are used, increase awareness of the importance of financial and non-financial indicators for assessing the effectiveness of innovation activity.

This empirical study was qualitative, which causes its main limitation. In-depth interviews as a qualitative method of collecting information are not representative, so their results cannot be extended to the entire population of industrial companies in Russia. In addition, the industry is quite diverse, so it is not possible to determine to what extent the surveyed companies are typical and characteristic of the industry.

Thus, quantitative research on the application of innovation metrics will be a priority for further research. It is also interesting to use performance metrics for innovative projects.

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Maize index insurance and management of climate change in a developing economy

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Abstract

This study provides an evaluation of the effectiveness of the maize index insurance in reducing the risk exposure of small-scale farmers in Zimbabwe. Maize yields and rainfall data for the period 2010–2019 farming season were obtained from AGRITEXT and the NASA website. The Black-Scholes optional pricing framework was applied to estimate the prices of the maize index insurance. The mean root square loss (MRSL) was evaluated for the case where there is no insurance and where there is insurance. MRSL was compared for the two scenarios. The index insurance was found to be efficient in risk reduction as positive changes in MRSL were observed.

Keywords: Agricultural insurance, Maize index, Farmers, Zimbabwe.

JEL: D4, D10, G1, G2, G13.

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Introduction

Changing climatic conditions is the main cause of the variability in the crop yields and hence there is an increase in the volatility [Ray et al., 2015]. M. Odening and Z. Shen [Odening, Shen 2014] also highlighted that the climate variability has an impact on the food security of the small-holder farmers and therefore undermines the financial contribution of the agricultural sector to the country's GDP. To manage these risks insurance has been used, but it faced many challenges, which have resulted in experiencing low uptake. Challenges facing insurance in many parts of the world is the high costs of full coverage of losses [Jensen et al., 2016]. Therefore, the smallholder farmers who do not afford these expenses remain exposed to the climatic risks. However, with the climate change frequency increasing the importance of managing the risk, exposure also increases, hence, there is a need for the development of index insurance for products which are considered more affordable than other insurance products. The index insurance for products have mainly been developed to address the low uptake of agriculture insurance among the smallholder farmers. The index insurance for product is affected by the challenges facing traditional agriculture insurance to a lesser extent. The maize index insurance resembles as an option. They pay out indemnity when the received cumulative rainfall is lower than the trigger level for the drought cover or when the seasonal rainfall exceeds the trigger level for the floods cover.

This article examines the efficiency of maize index insurance. The index insurance product is evaluated based on risk reduction for the six natural farming regions in Zimbabwe. The revenue of a farmer with index insurance is compared to that of the farmer without index insurance using the Mean Root Square Loss (MRSL). The article is organized as follows. The next section reviews literature on the efficiency of index-based insurance. Section 3 describes data and methodology to compare the risk reduction generated by the maize index insurance product. Section 4 presents the empirical results and discussion. We provide conclusions and recommendations in section 5.

1. Literature review

In South Africa, demand and development for index-based insurance is generally low as seen by low agriculture insurance for products that have swam out in Zimbabwe. The current viable insurance product is weather index based, which is offered by Econet and it is limited to three out of six regions. The major challenges that have been influencing the scalability of agriculture insurance were affected by the affordability of premiums and the trust that the policyholder has in the insurance provider [Carter, Janzen, 2012]. Part of the measures to reduce the risk exposure of the smallholder farmers emanating from climate variability index-based insurance has received increased attention from several research institutions [Miranda, Farrin, 2012]. For index insurance to cover adequately the farmer with little or no basic risk, the index used has to highly correlate with crop losses [Carter, Lybbert, 2012]. However, inadequate data are the main problem facing index design.

Potential buyers of the index insurance are also concerned about the ability of the contract to reduce their risk exposure in addition to its affordability. Therefore, it is important for the crop losses to correlate with the index used to improve risk management capability. To evaluate the risk reduction of the farmers' losses who purchased the index insurance contract, the Mean Root Squared Loss model (MRSL) is applied [Poudel et al., 2019]. According to [Kath et al., 2018] the calculation of MRSL based on the fact, that farmers are expected to be worried about revenue being below average. This method was also applied by S. Adhikari and coauthors [Adhikari et al., 2012], assuming a negative exponential utility function. MRSL was estimated using the revenue for the case where there is no index insurance and where there is insurance using the model below:

$$MRSL_{with} = \sqrt{\frac{1}{T}\sum_{t=1}^{T}[\max(p\bar{Y} - R^{with}), 0]^2},$$

$$MRSL_{without} = \sqrt{\frac{1}{T}\sum_{t=1}^{T}[\max(p\bar{Y} - R^{without}), 0]^2},$$
$$R^{without} = p\bar{y}_t,$$
$$R^{with} = p\bar{y}_t + Indemnity - Premium.$$

Where p is the price of maize, $\bar{Y}$ is the long-term average of the crop yield and $\bar{y}_t$ is the yield. [Poudel et al., 2019] employed the weather derivatives method to price rainfall index insurance and concluded that the average premium rates were 8.8%, thus, reducing the risk exposure of the farmers that purchase the index insurance contract by an average of 26% using the mean root squared loss to compare the risk exposures. J. Kath [Kath et al., 2018] found that the contract including flood cover for sugarcane was inefficient in risk reducing as the contracts with strike price at 70th and 80th percentiles as their trigger increased the losses; and the 90th and 95th percentiles exhibited no change in the losses. J.K. Poussin and coauthors [Poussin et al., 2015] used the regression models to evaluate the effectiveness of risk reduction and found that useful risk management tools include the household mitigation strategies.

2. Data and methodology

The maize yields and rainfall data used were obtained from AGRITEX and NASA website respectively. For the study, the data ranged from October 2009 to May 2019 for rainfall data and the period from 2010 to 2019 for the maize yields data were used. The Black-Scholes optional pricing framework was used to assess the contract in the study. Normalized yields and seasonal rainfall data for the region were used in the premium estimation process. Regional data were obtained from averaging the district data in the corresponding regions. The MRSL was calculated for the case where there is no insurance and for the case where there is index insurance. The MRSL was calculated using the revenues for both cases.

3. Empirical results and discussion

This section summarises the descriptive statistics (tools, standard deviation, minimum and maximum) of the data used in the research. The descriptive statistics for the sample districts that is used to come up with the regional data are presented in the table 1. According to [Mushore, 2013], the Zimbabwean rainfall season ranges from mid of November to mid of March of the following year. Therefore, the cumulative seasonal rainfall in this study was taken as the cumulative rainfall for the period from the beginning of October to the beginning of May to account for the late planted crops, contradicting with [Mushore et al., 2017] the period ranged from the 1st of October to the 31st of March of the next year. The seasonal descriptive statistics for the respective regions for the period 2010-201is summarised below.

The average rainfall received in region I, IIA, IIB, III, IV and V is 701.39 mm, 759.96 mm, 743.45 mm, 660.02 mm, 468.25 mm and 324.95 mm respectively. The average rainfall generally decreases across the regions.

3.1. Analysis of relationship between maize yield and seasonal rainfall

The relationship between the maize yields and rainfall was examined using different regression models that include linear, log linear and quadratic models. The maize yields data were detrended and normalized to remove the effects of heteroskedasticity and time trends using model 1 and 2. The normalized maize data is presented in the appendix. To test the relationship between the variables the original seasonal data were used in the case of independent variable and normalized maize yields were used in the place of dependent variable. The correlation coefficients R^2 were compared. The results from the regression models analysis are summarised in the table 2.

The relationship between maize yields and rainfall was modelled better using the quadratic regression model (for all regions) compared to linear regression and nonlinear regression for region I, IIA, IIB, III, IV, V respectively. This is indicated by the highest R^2 values of 0.01, 0.07, 0.22, 0.03, 0.26 and 0.01 for regions I, IIA, IIB, III, IV and V respectively being obtained from the quadratic regression model; This showed that the maize yields increase with rainfall to a limit point where it starts to decrease with excessive rainfall. Beyond this point the maize yields begin to decrease hence the need for index insurance that will cover both drought and floods. This is similar to the findings of [Mushore et al., 2017], who concluded that the relationship between maize yields and rainfall in Mt Darwin is better modelled by a quadratic regression model with R^2= 0.630. These findings are also in contradiction with those of [Poudel et al., 2019] who found that the crop yields were linearly related to the rainfall data. This is due to the difference in the crop type examined and the sample population.

Table 1
Descriptive statistics of maize yields and seasonal rainfall

District/ Region		Means	Median	Standard deviation	Sample variance	Minimum	Maximum
Chipinge	Seasonal rainfall	704.57	658.28	186.03	34608.71	491.30	1138.49
	Maize yields	0.54	0.55	0.16	0.02	0.25	0.76
Nyamapanda	Seasonal rainfall	698.21	669.44	154.46	23858.59	476.66	990.67
	Maize	0.52	0.55	0.14	0.02	0.24	0.71
I	Seasonal rainfall	701.39	656.71	139.73	19525.40	483.98	971.90
	Maize yields	0.53	0.56	0.14	0.02	0.25	0.71
Bindura	Seasonal rainfall	799.22	860.56	153.95	23700.12	610.97	1058.69
	Maize yields	0.56	0.57	0.18	0.03	0.33	0.79
Shamva	Seasonal rainfall	703.26	708.96	122.03	14891.81	487.37	871.22
	Maize yields	0.55	0.51	0.19	0.04	0.33	0.87
IIA	Seasonal rainfall	759.96	817.00	129.91	16876.64	556.88	924.36
	Maize yields	0.53	0.51	0.18	0.03	0.33	0.83
Mt Darwin	Seasonal rainfall	754.94	768.88	112.39	12630.41	537.48	979.32
	Maize yields	0.36	0.34	0.11	0.01	0.24	0.59
Hwedza	Seasonal rainfall	731.95	747.42	170.33	29011.67	425.71	1013.18
	Maize yields	0.36	0.39	0.11	0.01	0.19	0.48
IIB	Seasonal rainfall	743.45	756.75	128.62	16542.18	526.10	996.25
	Maize yields	0.36	0.36	0.11	0.01	0.22	0.53
Mvuma	Seasonal rainfall	650.96	657.86	138.85	19280.12	459.84	845.74
	Maize yields	0.30	0.33	0.12	0.01	0.11	0.48
Binga	Seasonal rainfall	669.09	727.25	140.16	19643.90	417.10	831.41
	Maize yields	0.32	0.38	0.18	0.03	-0.07	0.52
III	Seasonal rainfall	660.03	683.32	129.78	16843.32	441.92	828.46
	Maize yields	0.31	0.31	0.09	0.01	0.20	0.47
Tsholotsho	Seasonal rainfall	611.18	589.24	123.80	15326.57	455.95	836.95
	Maize yields	0.21	0.16	0.08	0.01	0.14	0.35
Bubi	Seasonal rainfall	638.72	606.89	93.53	8748.54	507.70	834.29
	Maize yields	0.22	0.18	0.08	0.01	0.14	0.35
IV	Seasonal rainfall	468.25	447.22	121.50	14762.92	308.59	675.00
	Maize yields	0.17	0.14	0.06	0.00	0.12	0.27
Beitbrigde	Seasonal rainfall	382.63	354.56	145.07	21044.80	240.58	713.38
	Maize yields	0.16	0.14	0.04	0.00	0.12	0.23
Zaka	Seasonal rainfall	553.87	522.95	163.56	26752.62	346.46	845.40
	Maize yields	0.18	0.16	0.07	0.01	0.11	0.32
V	Seasonal rainfall	624.95	587.70	105.58	11147.84	504.56	835.62
	Maize yields	0.21	0.17	0.07	0.01	0.15	0.35

Source: authors' analysis.

Table 2
Regression models results

	Region	I	IIA	IIB	III	IV	V
Linear model	R^2	0.00	0.05	0.18	0.02	0.16	0.00
	Intercept	717.90	841.66	484.46	783.43	789.95	461.61
	X Coefficient	-24.40	-127.90	597.30	-266.64	-580.07	26.12
Log Linear model	R^2	0.00	0.03	0.20	0.02	0.13	0.00
	Intercept	691.14	725.42	966.87	563.94	461.15	474.36
	X Coefficient	-24.29	-65.60	260.67	-122.93	-126.70	4.33
Quadratic model	R^2	0.01	0.07	0.22	0.03	0.26	0.01
	Intercept	857.25	630.15	-5.18	1452.05	362.08	688.91
	X Coefficient	-505.03	559.39	2965.48	-3285.75	3036.82	-1939.94
	X^2 coefficient	385.66	-508.46	-2745.61	3330.90	-7022.84	3908.56

Source: authors' analysis.

Table 3
Trigger levels (percentiles)

Percentile	Region I	Region IIA	Region IIB	Region III	Region IV	Region V
10^{th}	594.770	644.753	593.431	493.084	518.885	334.415
25^{th}	621.459	680.625	687.630	580.734	558.972	380.112
50^{th}	656.706	786.940	756.750	683.316	587.700	447.216
60^{th}	690.022	818.359	772.423	693.067	630.934	470.345
75^{th}	767.382	858.510	796.482	752.370	690.402	569.811
90^{th}	869.876	879.518	839.533	816.360	741.217	605.351

Source: author's analysis.

3.2. Premium Rate estimation

Determination of trigger values. The trigger levels for drought coverage were the lower percentiles i.e. (10^{th}, 25^{th}, and 50^{th} percentiles) whereas the upper percentiles i.e. (60^{th}, 75^{th}, and 90^{th} percentiles) were used as the trigger levels of the floods coverage. Therefore, the trigger values for the contract will be (10^{th} and 60^{th}), (25^{th} and 75^{th}) and (50^{th} and 90^{th}). The percentiles for each region are summarised in table 3.

Lognormal test of seasonal rainfall data. When pricing the options using the Black-Scholes framework it is assumed $\frac{S_T}{S_o}$ to follow a lognormal distribution. Hence it is necessary to examine if $\frac{I_T}{I_o}$ follows a lognormal distribution. Q-Q plots for the rainfall data were plotted to indicate that the data follows a lognormal distribution, the plots are presented in the appendix. To prove that the data follow a lognormal distribution, Kolmogorov – Smirnov Test and Shapiro – Wilk Test were carried out using SPSS.

H_o = the ln (seasonal rainfall) follow Normal distribution.

H_1 = the ln (seasonal rainfall) do not follow Normal distribution.

The p-values of the both the Kolmogorov test and Shapiro – Wilk test are both greater than 0.05, therefore we conclude that the natural logarithm of the seasonal rainfall data with maize follows a normal distribution hence the data follow a lognormal distribution, hence we accept H_o. The results of these tests are presented in table 4 below.

Pricing. In this case we consider a contract that pay out indemnity at a rate of 1 in the event of either drought or floods. Therefore:

Pay-out = Pay-out rate x the insured amount of yields x the preagreed value of 1 unit of maize yields.

The contract resembles an exotic combination option, which consists of a cash or nothing put option struck at the lower percentiles and a cash or nothing call option struck at the

Table 4
Normality test results

	Kolmogorov – Smirnov[a]			Shapiro – Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Region1	0.196	10	0.200[b]	0.967	10	0.864
Region 2A	0.214	10	0.200[b]	0.932	10	0.465
Region 2B	0.167	10	0.200[b]	0.961	10	0.796
Region 3	0.198	10	0.200[b]	0.936	10	0.513
Region 4	0.196	10	0.200[b]	0.941	10	0.561
Region 5	0.152	10	0.200[b]	0.965	10	0.836

[a] Lilliefors Significance Correction
[b] This is a lower bound of the true significance.

upper percentiles. Therefore the premiums paid by the insured will be the total of the premiums paid if the farmer were to purchase these options separately (drought and floods insurance separately).

Premiums = Premium of long cash or nothing put option + premium of a long cash or nothing call option.

The premiums paid by a farmer from region 3 are calculated as follows:

$$d_2 = \frac{\ln\left(\frac{I_o}{I_T}\right) + \mu t}{\sigma\sqrt{t}}$$

$$\mu = \frac{1}{n-1} \times \ln\left(\frac{I_n}{I_1}\right)$$

$$\sigma = \frac{1}{n-1}\sum_{i=1}^{n}(u_i - \bar{u})^2 \text{; where } u_i = \ln\left(\frac{I_t}{I_{t-1}}\right) \text{and } \bar{u} = \frac{1}{n}\sum_{i=1}^{n} u_i$$

I_0 = the last entry of the cumulative seasonal rainfall as it is the most recent, in the case of region IIB = 600.912

$t = 1$

$$\mu = \frac{1}{n-1} \times \ln\left(\frac{I_n}{I_1}\right) = \frac{1}{10-1} \times \ln\left(\frac{600.912}{701.292}\right) = 0.008251$$

$\sigma = 0.28108$

$r = 0.05$ (assumed)

Price of cash or nothing put option = Payout × e^{-rt} × $N(-d_2)$

$$d_2 = \frac{\ln\left(\frac{I_o}{I_T}\right) + \mu t}{\sigma\sqrt{t}} = \frac{\ln\left(\frac{600.912}{593.4312}\right) + 0.008251)}{0.281087} 0.073921$$

$N(-d_2) = 0.470537$

I_T = the 10^{th} percentile = 593.4312

Payout rate = 1

Premium of put option = $1 \times e^{-0.05} \times 0.470537 = 0.447588$

Price of cash or nothing call option = Payout × e^{-rt} × $N(d_2)$

$$d_2 = \frac{\ln\left(\frac{I_o}{I_T}\right) + \mu t}{\sigma\sqrt{t}} = \frac{\ln\left(\frac{600.912}{772.4232}\right) + (0.008251)}{0.281087} = -0.86391$$

$N(d_2) = 0.19382$

I_T = the 60^{th} percentile = 772.4232

Payout rate = 1

Price of cash or nothing call option = Payout × e^{-rt} × $N(d_2) = 1 \times \times e^{-0.05} \times 0.19382 = 0.184367$

Overall premium = Price of cash or nothing put option + Price of cash or nothing call option = 0.447588 + 0.184367 = 0.631955

There premium rate paid for both drought and floods cover is 0.631955 for a payout rate of 1 in the event of either floods or drought.

Premium price effects of trigger levels

The premium rates for other regions at different trigger levels, i.e. percentiles are summarised in table 5. From this table it can be deduced that for region 3 the premiums grow with an increase in trigger value, hence highlighting the importance of trigger values when pricing the contract. The premium for the drought cover increased by 30.34% when the trigger grew from 493.084 mm (10^{th} percentile) to 580.734 mm (25^{th} percentile). When the trigger grew from 693.067 mm (60^{th} percentile) to 752.37 mm (75^{th} percentile) the premium rate for the floods scenario cover decreased by 62.98%. The overall premium increased by 20.89%. The percentage changes of premiums as the trigger values increase are summarized in table 6.

We concluded that on average when the trigger value for the drought cover increases, the price of the contract also rises as the probability of rainfall being lower than the trigger value, hence there are higher chances of loss materialization to the insurance company. This conclusion is also similar to that of [Nyawo, 2017] who found out that the price of drought index insurance increases with trigger levels. The cost of floods insurance cover decreases with the increase in the trigger levels of the contract due to poor probability of the payment with lower expectation of costs.

Risk Reduction. To evaluate the effectiveness of the contract the current price of maize was 1171 USD per tonne in May 2019 according to FAO (2019). The study compared the changes in the mean root square loss in the situation of index insurance and visa versa. The MRSL model below was applied, the results of the model are presented in the table 6.

Table 5
Estimated premiums

	Trigger	Region I	Region IIA	Region IIB	Region III	Region IV	Region V
Premiums of drought cover (1)	10^{th}	0.1946	0.2195	0.4476	0.4651	0.5365	0.5705
	25^{th}	0.2347	0.3022	0.6409	0.6677	0.6490	0.7015
	50^{th}	0.2906	0.5618	0.7472	0.8189	0.7166	0.8266
Premiums of floods cover(2)	60^{th}	0.6059	0.3212	0.1844	0.1224	0.1547	0.0967
	75^{th}	0.4796	0.2450	0.1572	0.0751	0.0823	0.0309
	90^{th}	0.3311	0.2105	0.1170	0.0433	0.0459	0.0203
Overall premiums (1+2)	10^{th} and 60^{th}	0.8005	0.5407	0.6320	0.5876	0.6911	0.6672
	25^{th} and 75^{th}	0.7143	0.5472	0.7981	0.7428	0.7313	0.7324
	50^{th} and 90^{th}	0.6218	0.7723	0.8642	0.8621	0.7625	0.8469

Source: author's analysis.

Table 6
Mean Root Square Loss (MRSL)

Region	I	IIA	IIB	III	IV	V
MRSL without	142.5886	173.81	74.17606	58.69827	64.18613	60.71852
MRSL with	94.51939	147.7251	49.95188	42.57162	63.89767	43.38891
% Change	0.337118	0.150077	0.326577	0.274738	0.004494	0.285409
MRSL without	142.5886	173.81	74.17606	58.69827	64.18613	60.71852
MRSL with	73.20054	136.5942	39.6707	10.46631	39.41078	44.41062
% Change	0.486631	0.214118	0.465182	0.821693	0.385992	0.268582
MRSL without	142.5886	173.81	74.17606	58.69827	64.18613	60.71852
MRSL with	121.8747	71.1265	11.88402	40.41218	50.29615	36.02826
% Change	0.14527	0.59078	0.839786	0.311527	0.216402	0.406635

Source: author's analysis.

The Mean Root Squared Loss method was applied for all combinations of trigger levels to examine the performance of the index insurance in risk reduction. The results of the evaluation showed the same pattern for all the combinations in the table 6. The analysis of MRSL showed that the contract was efficient in reducing risk for all the trigger levels for all the regions. The greatest risk reduction was experienced. These finding are similar to those of [Poudel et al., 2019] who observed no risk reduction on their study on wheat. They also observed risk reduction on the out-of-sample category for rice. Authors [Kath et al., 2018] also observed no risk reduction for all trigger levels.

4. Conclusions and policy recommendations

The effectiveness of the contract in risk reduction was evaluated by comparing the mean root square loss of the farmer with and without insurance. It was observed that the combination of trigger levels used for the contract was efficient as positive percentage changes of MRSL were observed between the two scenarios for all regions.

The research observed that maize index insurance is viable in Zimbabwe and efficient in risk reduction hence the product is recommended to be used as risk mitigation tool for smallholder farmers. It was found that for the product to be attractive and economically viable the index should be accurately measured and this can be done when the equipment at the meteorological centres is modernized. Hence, there is a need for modernization of the stations. There is a need for IPEC to introduce a regulatory framework to provide standards that will protect the consumer and the provider. These standards will include clear index certification and minimum capital to liability holdings for the providers. The regulator should also update the existing definition of insurance to accommodate index insurance.

The government, IPEC, and Non-Governmental organizations among other stakeholders should consider subsidies to the firms that will pilot the introduction of the index-based insurance product to cushion them from adverse effects of large sunk costs. These costs arise from educating the smallholder farmers, as a majority of them are not fully aware of the formal insurance product existence.

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Prosumers: An overview of innovative models of interaction between subjects of the electric power industry and end consumers

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Abstract

Technological changes taking place in Russia and in the world have an impact on many sectors of the economy, including the electric power industry. There has been a tendency for consumers to withdraw from centralized power supply due to a wide range of factors: the spread and cheapening of generation technologies using renewable energy sources, energy storage systems, as well as the development of smart metering systems. The proliferation of digital technologies of Industry 4.0 allows innovative energy technologies to be integrated together.

The purpose of this work was to identify and verify the effects generated by the technologies of the fourth industrial revolution in the electric power industry, and the resulting new models of interaction between consumers and energy companies in the electricity market.

At the beginning of the study, the effects of the spread of distributed generation (including the use of renewable energy sources), energy storage systems, smart electricity metering systems, as well as digital technologies of industry 4.0 were identified, and the impact of these technologies on changing the nature of consumer interaction and energy companies.

Further, the analysis of the main approaches to organizing the interaction of energy companies with a new type of electricity consumers - an active consumer, is carried out, and the key effects from the spread of active consumer models are determined.

At the end of the work, industry experts were interviewed with subsequent questionnaires, which made it possible to assess the prospects for deploying active consumer models.

Keywords: smart metering systems, energy complex, digitalization, distributed generation, prosumer.

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Introduction

The current market model of the Russian electric power industry is facing significant challenges such as rising electricity prices for end consumers stipulated by the outpacing inflation growth in prices for both electricity and capacity in the energy market, as well as growth in tariffs for transmission services electricity and sales allowances, the complexity and high cost of technological connection to power grids and increase in capacity, and in the volume of cross-subsidization[1].

The NTI EnergyNet roadmap highlights a number of internal problems of the Russian energy sector, such as relatively long distances and lower load density of the power grid complex, high capital and construction costs, low installed capacity utilization factor of the power system as a whole, as well as low labor productivity[2].

In addition to the challenges that have matured in the current market system, there are a number of technological changes taking place in Russia and in the world, including the trend to abandon centralized power supply due to a wide range of factors: the spread of energy generation by means of renewable energy sources, the growth in demand for electricity, changing consumer behavior [Trachuk, Linder, 2018]. The centralized energy supply is being replaced by decentralized (distributed generation), which includes not only low-power generators, but also price-dependent energy reduction programs, smart grids, and energy storage systems [Frankel, Wagner, 2017.

This trend is facilitated by the spread and cost-cutting of generation technologies using renewable energy sources [Digital transition.., 2017], technologies of energy storage systems [Application of energy storage systems.., 2019], including those using hydrogen[3], as well as the development of smart metering systems [Kuzmin, 2021]. The trend that allows to integrate innovative energy technologies, new energy sources and smart metering systems is the spread of industry 4.0 digital technologies [Ivanov et al., 2018].

The combination of these trends leads to the transformation of the Russian electric power complex, changes in current and the emergence of completely new models of interaction between end consumers and energy companies, such as smart grids [Khovalova, Zholnerchik, 2018], Internet energy [Nalbandyan, Khovalova, 2018][4], as well as models of active consumers – prosumers who no longer want to be in a price-taking position and seek to actively participate in electricity trade [Digital transition.., 2017; Kuzmin, 2019].

A number of researchers conclude that the impact of the digital transformation of the electric power industry will be the strongest on the side of electricity end consumers [Digital transition.., 2017; Khokhlov et al., 2018; Khovalova, Zholnerchik, 2018]. Moreover, the most significant changes will affect end consumers in the retail market and, as a result, territorial grid organizations and energy sales companies that directly interact with end consumers.

The challenges facing the current market electric power industry in Russia, global technological trends, as well as changes in end-user behavior patterns contribute to the transformation of the electricity market in general and the retail market in particular.

The purpose of this work is to identify the effects generated by the technologies of the fourth industrial revolution in the electric power industry, and the resulting new models of interaction between consumers and energy companies in the electricity market.

1. Technical and economic features of the key technologies of the energy transition

In order to describe promising models of interaction between consumers and energy companies, it is necessary to consider in more detail a number of digital energy technologies that actively involve consumers in the processes of generation and consumption of electricity. Research suggests that traditional centralized energy systems will undergo significant changes due to the growing competitiveness of distributed, decentralized generation relative to centralized models built on fossil fuels as a primary energy resource [Wegner et al., 2017][5]. According to the reports of the International Energy Agency (IEA), there is a significant trend in reducing the cost of distributed generation using renewable energy sources (RES). For example, the price of wind turbines from 1980 to 2013 decreased by 10 times, while by 2014 the fall in prices for photovoltaics was 75% compared to the price of 2009[6].

1.1. Distributed generation

One of the main trends in the transformation of the electric power industry is the spread of distributed generation. According to a study [Trachuk, Linder, 2018], about 12.5% of industrial enterprises around the world use distributed generation (the share of such enterprises in Russia is 6%). At the same time, a study by the Energy

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Center, Skolkovo School of management [Khokhlov et al., 2018] predicts that among the total increase in the installed capacity of the energy system by 2035, about 12 GW will be covered by generators with an installed capacity of less than 25 MW.

Distributed generation technologies can include gas turbine generators, low-capacity combined cycle gas and gas piston units [Hansen, Bower, 2004], renewable energy-based power plants (including wind and solar generators) installed end-use. Distributed generation facilities can refer to installations operating in a cogeneration cycle (including those for power and heat supply to isolated energy regions), as well as low-capacity nuclear power plants [Sellyakhova et al., 2016].

Despite the fact that today the share of RES in the installed capacity of the Unified Energy System of Russia (UES) is relatively small and amounts to 1.12%, its further growth is predicted. One of the main drivers of the growth in the prevalence of RES is their cheapening.

However, in Russia the rates of RES distribution are significantly lower than the global ones. This is mainly due to the historical structure of the energy system, climatic and geographical features and, as a result, the relatively low cost of electricity consumed from a centralized energy system using traditional energy sources [Linder, Trachuk, 2017]. On the side of the population, the development of RES is slowed down by cross-subsidization, which provides a lower cost of electricity for the population, covering the gap with the cost price at the expense of industrial consumers [Trachuk, Linder, 2017].

In the work G.G. Nalbandyan and S.S. Zholnerchik distinguishes the areas of distributed generation use that are characteristic of the Russian energy system [Nalbandyan, Zholnerchik, 2018]. Distributed generation can be applied:

1) for the autonomous production of electrical, thermal energy (in the case of work in a cogeneration cycle), as well as cold (in the case of trigeneration);
2) when operating in parallel with the unified energy system to generate electricity during the hours of high peak prices in the UES and reduce the resulting electricity costs;
3) in the power supply of facilities that require a high level of quality, reliability and uninterrupted power supply, which cannot be provided with supplies from the unified energy system;

Table 1
Comparison of the effects created by distributed generation with participants in the electricity and capacity market

Direction of influence	Potential effect from the spread of distributed generation
End users: industry, business and households	1. The possibility of autonomous production of electrical, thermal energy, as well as cold 2. Reducing the resulting costs for electricity during the hours of high peak prices in the UES in parallel operation with a unified energy system 3. Increasing the level of quality, reliability and uninterrupted power supply 4. Improve sustainability and reduce CO_2 emissions 5. Use of alternative fuels such as biogas, pyrolysis oil, associated gases, etc. 6. A source of additional agility both to participate in smart grid models and for active consumer
Generating companies	1. The ability to introduce additional generating capacities in smaller volumes, more accurately adjusting to the dynamics of energy consumption growth 2. Improving the efficiency of investments in additional generating capacity
Electric grid companies	1. Reducing the need for construction of additional power grid capacities 2. Reducing losses in distribution networks 3. Reducing the number of outages and accidents in the power grid complex
Organizational structure of the electricity and capacity market	The emergence of new models of interaction between consumers and energy companies, including smart grids and models of active consumers
State Administration and regulators	Improving the quality and accuracy of decisions made on the strategic development of the electric power industry

Source: compiled by the author.

4) in the power supply of facilities with more stringent requirements for environmental friendliness and CO_2 emissions;
5) in projects involving the use of alternative fuels such as biogas, pyrolysis oil, associated gases, etc.

Another important effect from the spread of distributed generation is the ability to introduce additional generating capacities in smaller volumes, thereby more accurately adjusting to the dynamics of energy consumption growth and hedging the risks of irrational investments [Khokhlov et al., 2018]. In addition, distributed generation can reduce the need for the construction of additional power grid capacities [Trachuk, Linder, 2018].

Also, distributed energy is comparable in its energy efficiency (performance factor) with large power plants, but due to its proximity to the consumer, it is characterized by a lower level of network losses in the distribution of electricity. In addition to reducing losses, some studies note a decrease in the number of outages and accidents in the power grid complex [Nalbandyan, Khovalova, 2018][7].

In addition to technological effects, the spread of distributed generation can affect the commercial structure of the market and the mechanisms of interaction between energy companies and consumers. Thus, distributed generation is one of the key elements of smart grids that integrate the generation, distribution and consumption of electricity with the help of digital solutions and provide a bidirectional power flow [Khokhlov et al., 2018][8].

At the same time, the opportunity for consumers (including households) to sell surplus electricity produced on their own generation, both on traditional fuels and using renewable energy sources, can involve consumers in active participation in the electricity markets, thereby forming a new type of consumer – an active consumer [Klimovets, Zubakin, 2016].

A comparison of the effects created by the spread of distributed generation with the directions of influence are presented in Table 1.

1.2. Energy storage systems

The next significant trend is the spread of electricity storage systems (ESS).

The main factor in the spread of electricity storage systems is the peculiarity of electricity as a commodity: the volume of electricity production must equal the volume of consumption at any given time. Due to the fact that the daily consumption schedule is uneven and has pronounced consumption peaks, the power system must contain reserve capacities that can cover these peaks[9].

Storage systems are a technological solution that organically complements distributed generation technologies based on renewable energy sources. The stochastic nature of renewable energy generation due to dependence on weather conditions can be supplemented by accumulation systems that will smooth out uneven generation. In this case, ESS will act as storage when electricity generation exceeds the demand of the power system, and as a source when energy generation is not enough[10].

For a long time, such systems were not seriously considered due to weak economic indicators, however, the gradual industrial development and reduction in their cost makes it possible to consider the introduction of ESS and the creation of new network and system services[11].

The rapid growth in demand for solar energy is due to a decrease in prices for Li-ion storage, as well as the trend towards the development of distributed generation, including the predicted decrease in the cost of solar and wind generation [Use of energy storage systems.., 2019]. An additional incentive is the spread of electric transport, which, once connected to the grid, can act as a storage facility and participate in demand management mechanisms and active consumer models[12].

The Ministry of Energy in the "Concept on storage" suggests that ESS can be used as:

1) an autonomous source of energy, which allows to ensure a long term power supply of the facility without being connected to a unified power system;
2) an energy source in case of accidents, partially or fully providing electricity for the period of repair of the main source of electricity supply;
3) a way to control the energy consumption schedule - control of the consumed power due to the return or accumulation of electricity, depending on different periods of time;
4) a regulator of system parameters - a method for controlling the operating mode of an electrical system, maintaining frequency and voltage at the required intervals, as well as a method for reducing electricity losses in networks[13].

[Application of energy storage systems.., 2019], the list of possibilities of systems for accumulating their effects is expanded. In addition, the authors proposed grouping of ways to use ESS into four categories.

[7] See also: Distribution automation. Results from the Smart Grid investment grant program (2016). U. S. Department of Energy. https://www.energy.gov/sites/prod/files/2016/11/f34/Distribution%20Automation%20Summary%20Report_09-29–16.pdf.

[8] See also: Smart Grid 101 (s.a.). Berkeley Lab. Electricity Markets and Policy Group. https://emp.lbl.gov/sites/default/files/chapter1–3.pdf.

[9] Batrakov A., Shaposhnikov D. (2017). How energy storage technologies will change the world. RBC, 008 (2505). https://www.rbc.ru/newspaper/2017/01/19/587e404e9a7947208a047c9d.

[10] Concept for the development of the market for electricity storage systems in the Russian Federation. https://minenergo.gov.ru/node/9013.

[11] Energy storage for grid and ancillary services (2016). Navigant Research. https://www.navigantresearch.com/research/energy-storage-for-the-grid-and-ancillary-services.

[12] The impact of electric vehicles on the grid: Customer adoption, grid load and outlook (2016). Wood Mackenzie. https://www.woodmac.com/reports/power-markets-the-impact-of-electric-vehicles-on-the-grid-customer-adoption-grid-load-and-outlook-58120591.

[13] Concept for the development of the market for electricity storage systems in the Russian Federation. https://minenergo.gov.ru/node/9013.

1. System storage devices - ESS of relatively high power, used within the UES of Russia, connected to backbone networks or high voltage networks, with the possibility of issuing power to the network or its accumulation, can:

- participate in the system services market, namely in primary and secondary frequency regulation;
- to optimize the loading of sections of the main transmission lines by smoothing the peaks, as well as to participate in ensuring static and dynamic stability;
- serve as RES integrators. For systems and energy interconnections with a large amount of generation from renewable sources, ESS can smooth out the stochastic nature of renewable energy generation and ensure the required quality of electricity supplied to the grid.

These features make system ESS similar to peak generators and, accordingly, the cost-effectiveness of such ESS will determine the ability to compete with them. Despite the fact that ESS have restrictions on the time of issuing stored energy, they have a number of advantages, including a high rate of power output (or accumulation).

2. ESS applied at the level of distribution networks, in addition to the above listed ones, are capable of:

- unloading distribution network power centers;
- increasing the reliability of power supply by acting as a backup power source in case of accidents in higher voltage networks or other interruptions in power supply;
- improving the quality of electricity, stabilizing voltage and frequency.

3. Saving systems located end-use "behind the counter" have an even greater range of possibilities - they can:

- be used as an uninterruptible power supply end-use in case of accidents in networks;
- be used for equipment that is sensitive to power quality or equipment that requires continuity of the process. Thus, they ensure the required level of quality and continuity;
- reduce the cost of technological connection to networks, covering the difference between base and peak loads;

Table 2
Comparison of the effects created by the SNE with the participants in the electricity and capacity market

Direction of influence	Potential effect from the spread of accumulation systems
End users: industry, business and households	1. Application as an uninterruptible power supply end-use in case of accidents in networks 2. Ensuring the required level of quality and uninterrupted power supply for equipment sensitive to power quality or equipment that assumes the continuity of the technological process 3. Reducing the cost of technological connection to networks by covering the difference between base and peak loads 4. Reducing the resulting costs for electricity during the hours of high peak prices in the UES in parallel operation with a unified energy system 5. Source of extra agility both to participate in smart grid models and for active consumer
Generating companies	1. Increased operational efficiency, as well as the accuracy of the power plant installations following the load schedule 2. Participation in the system services market
Power grid companies	1. Optimization of section loading of the main transmission lines by smoothing the peaks 2. Participation in ensuring static and dynamic stability 3. Unloading power distribution centers 4. Increasing the reliability of power supply 5. Improve power quality, voltage and frequency stabilization
Organizational structure of the electricity and capacity market	Emergence of new interaction models between consumers and energy companies, including smart grids and models of active consumers

Source: compiled by the author.

- in the presence of their own distributed generation (including the use of RES), they are able to optimize the operating mode of generating equipment. Thereby, they increase its efficiency and extend its useful life, as well as reduce the balance of flows with UES networks.

4. Hybrid generator - ESS, located within the boundaries of the power plant balance sheet. With the help of such a drive, it is possible to increase operational efficiency, as well as the accuracy of following the load schedule by the installations located at the power plant.

At the same time, the use of ESS as a hybrid generator will be somewhat different for four groups of power plants:

- ESS as part of a large generator of the Unified Energy System;
- ESS as part of a small or local station;
- ESS linked to a generator with a high share of fuel costs;
- ESS as part of generators based on renewable energy sources.

The report of the consulting company VYGON Consulting notes that the greatest efficiency of of ESS use is achieved when they are used in different market segments at the same time. When applied to multiple commercial models jointly, for example, in order to provide system services and smooth out peak loads, storage can have an acceptable payback period tod[14].

Just as in the case of distributed generation, ESS are an additional source of flexibility for the participation of end users in demand management projects, and can also become one of the key technologies for building smart grids, microgrids and involving users in active consumer models [Nalbandyan, Khovalova , 2018; Application of energy storage systems.., 2019].

Comparison of the effects created by the spread of electricity storage systems with the directions of influence are presented in Table 2.

1.3. Intelligent electricity metering systems

Studies show that one of the main digital transition technologies in the electric power industry is the technology of intelligent electricity metering systems (IMS) [Khovalova, Zholnerchik, 2018]. Such systems are based on electricity meters equipped with modules for collecting, processing, storing, sending and receiving data.

Unlike traditional electricity meters, smart metering systems have a wider range of functions, these are:

- real-time monitoring of consumption volume;
- the possibility of aggregating data from various counters into a single database;
- storage of statistical data on electrical characteristics;
- Obtaining information on power flows and reliable determination of the level of technological and commercial losses in power grids;
- identification of unmetered energy consumption and facts of impact on meters;
- formation of energy saving strategies and assessment of their implementation;
- remote limitation of power consumption.

However, despite the existing extensive functionality of intelligent metering systems, IMS built on the basis of Non-Intrusive Load Monitoring (NILM) technology have even more capabilities. NILM is a method to analyze data on the total electrical load obtained by measuring the current and voltage at one point and then dividing the total load into the loads of individual devices [Kuzmin, 2019].

Researchers note that non-intrusive load monitoring technology can play a key role in the digital transition in the power industry [Zoha et al., 2012]. It cannot only improve the current operating activities of electric power companies, but also form the basis for the formation of new relations between energy market entities [Bergman et al., 2011; Lin and Wang, 2011].

IMS based on non-intrusive load monitoring have two key differences that determine the specifics of their application:

- non-intrusive – such an IMS meter measures current and voltage in one place of the building distribution network and does not require direct integration into the network, while providing measurement accuracy that is not inferior to traditional meters (including meters equipped with Wi-Fi and GSM modules);
- data disaggregation – currently, if it is necessary to separate energy consumption profiles for each device located in the room, a direct meter is installed at the entrance to each device. The NILM meter, using cloud technologies and special machine learning methods, breaks down the integrated energy consumption data collected at one point in the network into consumption profiles of each device. Since the cost of installing direct on-line meters is directly proportional to their number, the use of NILM sensors contributes to significant savings [Naghibi, Deilami, 2014]. This effect is even stronger when large commercial real estate is equipped with meters, as well as in industries using a large amount of equipment.

Based on their technological features, IMS are able to find application in many areas:

- Disaggregation of total energy consumption and visualization: with the help of NILM sensors, consumers are able to highlight the energy consumption of each device. The result of disaggregation in the form of an interactive infographic is displayed in a

[14] Energy storage in Russia: an injection of sustainable development (2020). VYGON Consulting. https://vygon.consulting/upload/iblock/e44/vygon_consulting_storage.pdf.

Table 3
Comparison of the effects created by the Smart meters with the participants in the electricity and capacity market

Participant of the electricity and capacity market	The effect from the introduction of an intelligent electricity metering system
Households	1. Split of the bill for electricity and identification of energy-consuming appliances 2. Optimization of the consumption profile when using a multi-zone tariff for the purchase of electricity and, as a result, cost reduction 3. Preventive control of breakdowns and malfunctions 4. Parental control and social monitoring 5. Involvement in effective load management and participation in demand management projects
Manufacturing and large commercial real estate	1. Separation of the bill for electricity and identification of energy-consuming appliances 2. Optimization of the consumption profile when using a multi-zone tariff for the purchase of electricity and, as a result, cost reduction 3. Preventive control of breakdowns and malfunctions 4. Separation of energy consumption by premises (especially relevant for real estate developers) 5. Control of unauthorized access to the equipment 6. Involvement in effective load management and participation in demand management projects
Management companies and housing and communal services	1. Improving the energy efficiency of apartment buildings and commercial real estate 2. Detection of illegal connection to electricity networks and reduction of the risk of electricity theft
Power grid organizations	1. Preventive control of breakdowns and malfunctions 2. Increasing the speed and accuracy of energy balance formation 3. Improving efficiency in combating unmetered energy consumption 4. Reducing the volume of technological and commercial losses in networks 5. Commercialization of data collected by smart accounting systems
Energy sales organizations and last resort suppliers	1. Increasing the efficiency of activities in the wholesale and retail electricity markets 2. Increasing the efficiency of participation in projects to implement the concept of load aggregator 3. Commercialization of data collected by smart accounting systems
State administration and regulators	1. Ability to analyze big data on energy consumption 2. Improving the quality and accuracy of decisions made on the strategic development of the electric power industry

Source: compiled by the author.

mobile application or in a custom online platform. The amount of useful data can be significantly increased by installing several sensors (for example, it is possible to divide energy consumption between floors in a multi-storey building or collect information on the workload of production equipment in various rooms of a large enterprise);

- Identification of non-normative operating modes of devices and preventive monitoring of breakdowns: since sensors collect data in real time, the system remembers patterns of device behavior. Using the methods of neural network analysis, the system recognizes changes in the operating mode of the device and promptly sends a notification to the user about the detected violation;
- Electricity bill splitting: Using the device-by-appliance splitting of energy consumption, you can split the bill in a proper way. With a differentiated cost of electricity by zones of the day, you can generate a report on the costs of operating the device in a given

period of time. Thus, it becomes possible to optimize the operation mode of devices, develop a schedule for optimal energy consumption and reduce the cost of purchasing electricity;

- embeddability in third-party solutions: device-by-device load sharing is one of the most important technological features of NILM. This solution can also be integrated into traditional direct on-line meters;
- sending alerts messages and notifications: by means of a mobile application or a user online platform the NILM system sends a user notifications about violations of device operation modes or when user-defined marks are exceeded (for example, if the stove operation time exceeds the set number of hours or when the specified energy consumption bar is exceeded).

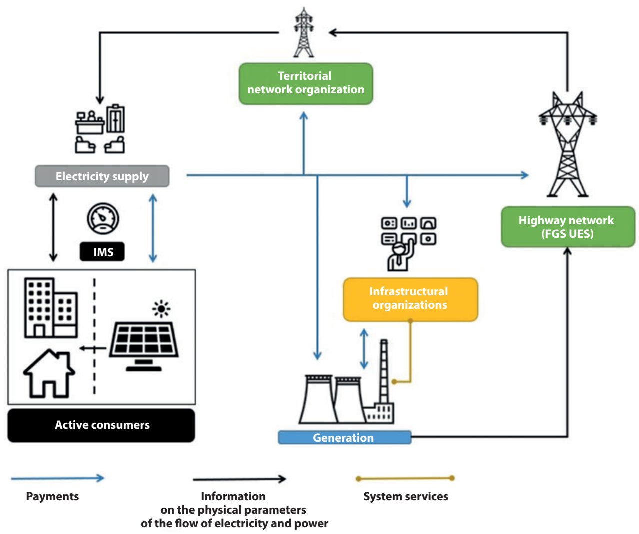
The introduction of intelligent electricity metering systems (including those based on NILM technology) generates a wide range of effects for both end consumers and companies in the electricity industry [Khovalova, Zholnerchik, 2018; Kuzmin, 2019]. Comparison of the effects created by the IMS with the participants in the electricity and capacity market are presented in Table. 3.

1.4. Industry 4.0 digital technologies

Industry 4.0 digital technologies are designed to become the information basis and link between the technologies described above. The key technologies include:

- digital twins. As part of online and offline decision support system development, digital twins make it possible to create mathematical models of generating equipment, networks, facilities, processes, etc., which in the future can increase the operational efficiency of energy companies[15];
- industrial internet of things. It allows you to collect data from remote objects and network devices. The internet of things is designed to provide machine-to-machine interaction, the exchange of information and guiding signals between the equipment of the local energy system [Architecture .., 2021];
- big data (Big Data). Big data received from intelligent network elements (primarily from IMS) and their subsequent processing will improve the efficiency of industrial enterprises, the quality of forecasting and decision-making in the future, as well as commercialize the collected data through their direct sale [Kuzmin, 2019];
- machine learning (Machine Learning). It allows automated processing of big data, as well as increases the optimality of decision-making on operational and prospective activitiesи[16];
- distributed registries (blockchain). Blockchain and Smart contracts technologies will allow to eliminate intermediaries in the chain of electricity sales to the end consumer and make the transition to automated Smart contracts, which is one of the basic elements of such active consumer models as the Internet of Energy [Architecture .., 2021].

Fig. 1. The basic model of the active consumer: A schematic diagram of interaction



Source: compiled by the author.

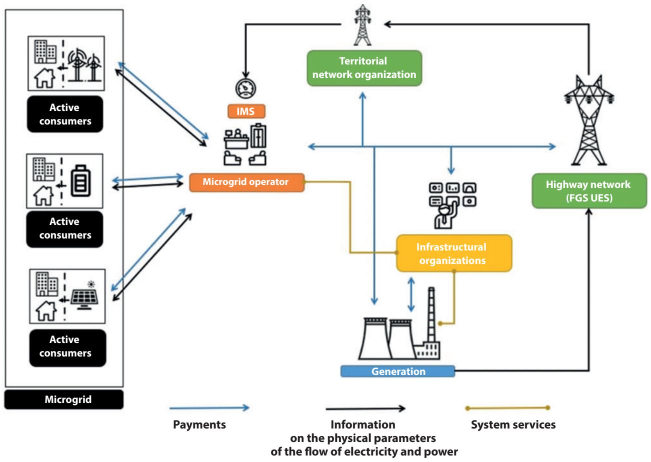
The study [Harnessing.., 2021] concludes that artificial intelligence technologies can significantly accelerate the digital transformation of the energy sector by identifying patterns and analyzing data, coordinating energy systems with a growing share of renewable energy sources, managing complex decentralized energy systems using distributed power generation, distributed storage and enhanced demand response capabilities.

Considering the spread of smart metering, energy storage systems, digital technologies that provide two-way information transit, load controllability will increase, which together with the spread of distributed generation can lead to the transformation of a passive consumer into an active one who is able to manage energy consumption, and in the presence of generating equipment - supply power to the network. Active consumers, who can not only change the energy consumption profile, but also generate energy and sell it to the grid, are often referred to in the literature as prosumers [Parag, Sovacool, 2016; Brown et al., 2019; Architecture.., 2021].

In a number of Russian studies in the field of demand management and digital technologies in the electric power industry, such as [Digital transition.., 2017; Demand management.., 2019], it is noted that not only large industrial consumers who know the wholesale market rules and use the flexibility of their production process to optimize costs, can participate in active consumer models. Their authors argue that a significant potential for demand management

[15] Concept. Digital Transformation 2030 (2018). PJSC Rosseti. https://www.rosseti.ru/investment/Kontseptsiya_Tsifrovaya_transformatsiya_2030.pdf.
[16] Id.

Fig. 2. Microgrid: A schematic diagram of interaction



Source: compiled by the author.

and balancing the energy system is concentrated in small consumers – retail market entities. Foreign studies also note the important role of small businesses and households in digital transformation and the trend towards the emergence of active consumers [Brown et al., 2019].

Thus, the combined influence of digital transition technologies in the electric power industry forms the prerequisites for the emergence of a new type of electricity consumer - an active consumer. This in turn can transform the current business models of energy companies and contribute to the formation of new value propositions not only for existing energy market participants but for subjects that have not previously interacted with those of the electric power industry.

2. Overview of active consumer models

The study [Parag, Sovacool, 2016] notes that active consumers have the opportunity to be directly involved in balancing the power system and providing system services by managing their load and (or) issuing power to the grid.

Despite the fact that the current market regulations and regulatory framework of most countries are focused primarily on the existing energy market model in the country, a number of promising interaction models can be proposed that are beneficial to all participants in the electricity trade [Brown et al., 2019]. These models reflect the main ways of organizing the interaction of consumers with energy companies and are not exhaustive.

1. The basic model of an active consumer. In the basic model, on the consumer side, before the meter, there may be a source of electricity or a storage device. Thus, the consumer can use electricity produced by a generator belonged to him and buy it from the network if his own energy production is not enough to cover consumption (for example, if the consumer has a RES generator installed and the weather conditions are not favorable for generation). If there is no generation or accumulation system, the consumer has the opportunity to change the load profile taking into account hourly or zone prices for electricity.

An important aspect of the basic model of an active consumer is the organization of both technological and market systems, which provides a bidirectional energy flow and allows an active consumer to supply excess power to the grid [Klimovets, Zubakin, 2016]. A schematic diagram of the interaction between subjects of the electricity market in the basic model of an active consumer is shown in Fig. 1.

The studies [Demand Management.., 2019; Brown, 2019] highlight a significant drawback of such a model, casting doubt on its viability. Consumers in the retail market (and sometimes in the wholesale market) have a relatively small amount of manageable load, which makes interaction with them unprofitable for infrastructure organizations: transaction costs significantly exceed the theoretical benefit. Thus, this model has limited opportunities to participate in active electricity trading.

2. Active energy complex/microgrid. This concept, shown in Fig. 2 is based on end-users and retail generators (including generating facilities owned by active consumers and/or power storage systems) connected to a low-voltage power grid in the microgrid area owned by the microgrid operator. Electricity is accounted for at the border of an active energy complex as a balance of generated and consumed electricity.

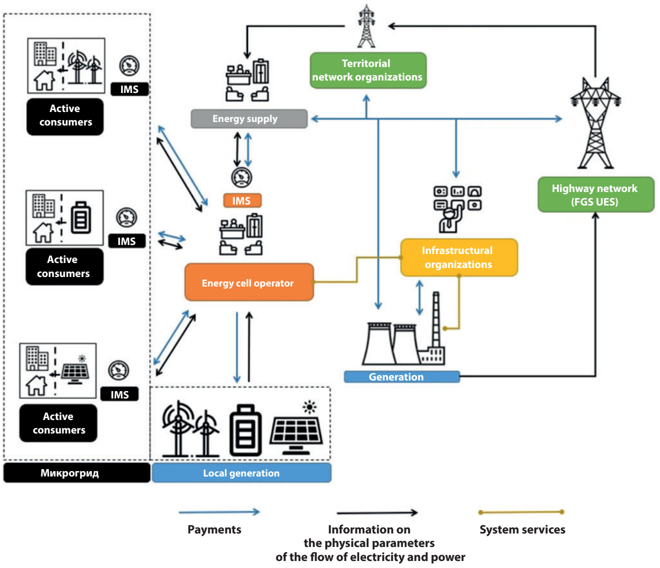
For a long time, the concept of a microgrid seemed applicable to power supply to isolated areas, the connection of which to a single power system would be economically unjustified. However, this concept turned out to be applicable in the case of a connection to a unified energy system as a model of an active consumer [Local supply.., 2018].

Also, the microgrid can be supplemented with the concept of a virtual power plant / virtual energy company. Such a company can provide billing services, as well as act as a demand management operator, thereby providing system services [Local supply.., 2018]. Based on a smart metering system, distributed generation and energy storage systems, with the help of price signals and various tariff solutions, a virtual energy company is able to reduce energy consumption during peak hours and optimize energy consumption at all the day to reduce the final cost of electricity for microgrid participants.

The paper [Brown et al., 2020] puts forward the idea that such models can have maximum efficiency for energy clusters under construction, since the costs of installing a smart metering system, storage and distributed generation will be taken into account at the design stage.

The world experience of pilot microgrid projects implemented for industrial and commercial consumers demonstrates a reduction in electricity costs from 5 to 25% (including participation in demand management programs), a reduction in CO_2 emissions into the atmosphere (which is especially important for industrial enterprises in the era of widespread decarbonization and the introduction of ESG principles) as well as improving the reliability and quality of

Fig. 3. Energy cell: A schematic diagram of interaction



Source: compiled by the author.

electricity supply. At the same time, it is noted that the final share of the reduction in energy supply costs depends on the configuration of specific participants in the microgrid, the potential costs for technological connection to the networks of the unified energy system (or upgrading networks to ensure large power flows), as well as on the requirements for the reliability of power supply and environmental friendliness[17].

It should be noted that in addition to the above listed effects, the introduction of microgrids with the widest functionality allows participants to act as additional sources of energy system flexibility and provide system services, including:

- participation in demand management projects;
- participation in frequency regulation;
- voltage regulation in the power system;
- provision of power reserves (including those for consumers outside the microgrid);
- reactive power compensation.

In order to test the microgrid concept and further develop this area in Russia, from 2020 to 2023, a pilot project is being carried out to organize active energy complexes, regulated by Decree of the Government of the Russian Federation No. 320 dated by March 21, 2020.

An active energy complex (AEC) is one of the types of microgrid used to supply industrial and commercial consumers with energy and unites both generators and consumers of eclectic energy and power entering into economic relations both within the active energy complex and with a unified energy system external to the AEC. The pilot project defines the AEC as a microgrid united with the UES, which includes generators with an installed capacity of up to 25 MW, which are not involved in electricity and capacity trading on the wholesale market, and consumers are represented by commercial and industrial enterprises, as well as business and shopping centers. At the same time, the balance of production and consumption of electricity within the AEC and the provision of power flows with the unified energy system within the permitted capacity is carried out by means of controlled intelligent connection.

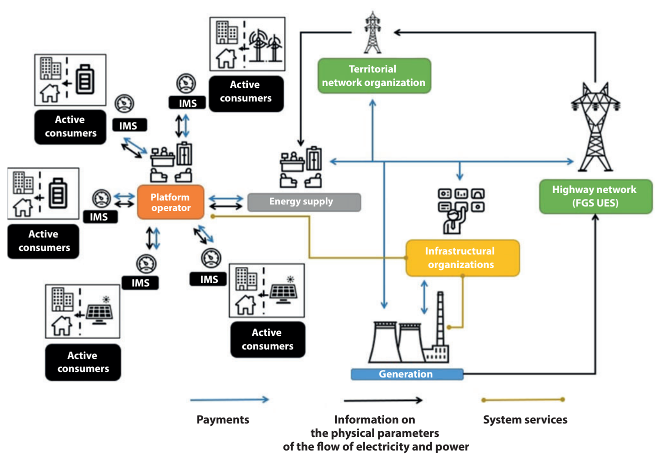
It should be noted that in addition to the opportunities for energy companies to participate in microgrid projects as their operators, the spread of microgrids opens up opportunities for implementing business models related to the export of technologies and the provision of implementation services. The active development of commercial and industrial microgrids creates a window of opportunity for Russian energy and technology companies for high-tech export of their solutions[18].

At the moment, the main barriers to the development of microgrids and AECs in the Russian market are regulatory barriers that do not allow retail market participants to freely and transparently organize energy exchange and share power grid capacities.

The world experience of piloting microgrids shows that the key to success in this dynamically developing market is the use of high-tech solutions and innovative business models both by end consumers of electricity and by companies operating microgrids. Implemented microgrids should be able to adapt to the conditions of a rapidly changing energy market, as well as consumer demands. Thus, the following technologies are of great importance for the creation of efficient microgrids throughout the entire life cycle:

- energy sources diversified by generation types;
- electric power storage systems;
- power receiving devices with the ability to control the load;

Fig. 4. P2P model: A schematic diagram of interaction



Source: compiled by the author.

[17] Microgrids for commercial and industrial companies (2017). World Business Council for Sustainable Development.
Microgrid analysis and case studies report (2018). California Energy Commission.
[18] Active energy complexes... https://drive.google.com/file/d/1PwyNYskwbaES_5oE3utFDDOnbucosZ0q/view.

- digital technologies for integration and management of microgrids (including those using artificial intelligence), providing plug&play connection of microgrid participants.

Thus, active energy complexes / microgrids are promising models of an active consumer in the retail market, which have a high development potential in conjunction with the spread of digital transition technologies in the electric power industry.

3. Energy cell. The concept of an energy cell (or local energy company), the schematic diagram of which is shown in Fig. 3 is in many respects similar to the microgrid concept, however, unlike the microgrid, the energy cell also includes local distributed generation connected to other consumers and microgrids through networks of territorial grid organizations.

Just like microgrids, energy cells seek primarily to provide energy exchange between producers and end consumers within the cell, if necessary, using power from a single power system.

The concept assumes more effective interaction of active consumers with the owners of distributed generation included in the energy cell, thereby it contributes to the establishment of lower electricity prices.

When using digital control technologies, as well as intelligent metering systems, it becomes possible to use dynamic pricing, which allows optimizing the load of generating capacities and consumption volumes inside the cell and leading to the establishment of an economically justified price for electricity [Brown et al., 2019].

Pilot projects in the UK have shown that the positive economic impact of deploying such models is achieved primarily by reducing the grid component in the electricity price structure, optimizing the cell's power schedule, selling electricity during peak consumption hours in the grid and participating in demand management programs.

In Russian studies, the concept of an energy cell is expanding from an independent concept to a participant in a more complex innovative model of interaction - the Internet of Energy. At the same time, an energy cell is one of the key elements of the Internet of energy and can act as an active consumer for neighboring energy cells, thereby trading electricity with them [Architecture .., 2021].

4. P2P model / internet energy. Peer-to-peer business models (Fig. 4) are based on the elimination of the electricity supplier as an intermediary between active consumers. These models use a third-party platform where consumers trade electricity among themselves. The promise of these models lies in fairer pricing, as the price is set by bidding between active consumers rather than determined by a third-party supplier. If generating capacities of active consumers are not enough to balance the platform participants, or, conversely, there is an excess, electricity can be purchased from the centralized power system or sold to it [Brown et al., 2020; Architecture.., 2021].

In Russian studies, the phrase “Internet of energy” is more often used to refer to the P2P model, although a common understanding of the term has not yet been formed.

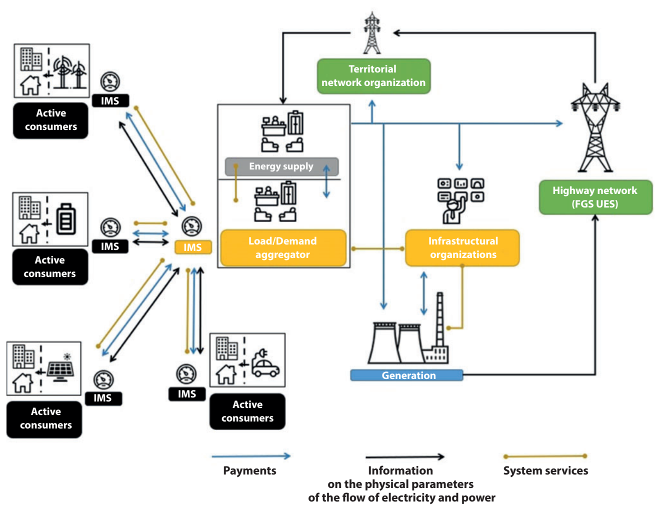
Despite the ambiguity of interpretations, general provisions can be distinguished in the description of the Internet of energy:

- the system is implemented on the basis of information technologies that ensure the exchange of information between participants in the Internet of Energy;
- the system should provide a balance between the production and consumption of electricity among active consumers, who own, among other things, distributed generation, generation based on RES and energy storage systems;
- Internet of energy is a cyber-physical system in which information flows are aimed at establishing the optimal mode of the system operation and ensuring reliable and high-quality power supply;
- To ensure bidirectional flows of both electricity and information in the Internet of Energy, digital sensors and actuators are used to control and monitor the state of the system [Nalbandyan, Khovalova, 2018].

Thus, the Internet of Energy is, in fact, an application to power systems of the Internet of things concept, which is a group of devices and equipment connected to intelligent computing networks which use data collected from devices for their active control. With regard to the electric power industry, these can be both built-in sensors that control the operation of turbines and intelligent control systems for distribution substations, as well as sensors and actuators installed on the consumer side and allow real-time control of the load.

The main drivers for the development of the Internet of Energy are the need to integrate distributed generation

Fig. 5. Risk map with a new technological level



Source: compiled by the author.

(including stochastic generation based on renewable energy sources) into energy systems, increased requirements for the environmental friendliness of electricity supply and the growing popularity of feed-in tariffs as well as tightening the requirements for reliability and quality of electricity by high-tech sectors of the economy [Baer et al., 2002]. Thus, the study [Morley et al., 2018] predicts an increase in energy consumption by digital infrastructure and precision industrial production at the level of 7% per year, while the share of consumption of digital devices in peak energy consumption will also increase.

Also, the changing nature of consumption in the retail market stimulates the development of the Internet of energy: according to the forecast of McKinsey & Company the daily unevenness of the household energy consumption schedule with the widespread use of electric vehicles will increase by 30% compared to the current level [Engel et al., 2018], which will lead to the need for investment into additional capacity subject to a slight increase in the volume of electricity consumed, which in turn will lead to an increase in the capacity payment for end consumers.

The effects of implementing the concept of the Internet of Energy include both effects generated by the models discussed earlier, as well as unique ones arising from the use of more digital solutions than in other models:

- reduction of investments in generating and power grid capacities due to more accurate forecasting of the consumption schedule;
- reduction of losses in Internet energy networks due to optimization of flow routes;
- the most effective participation in demand management programs through a deeper analysis of end-user behavior patterns;
- the most efficient integration of distributed and renewable energy generation, as digital technologies will allow you to quickly respond to changes in generation;
- reducing operating costs and improving the reliability of power supply due to predictive equipment analytics;
- creating unique value propositions for end consumers by collecting and processing big data from consumer devices [Nalbandyan, Khovalova, 2018; Brown et al., 2020; Architecture.., 2021].

Just as in the case of microgrids, the development of the Internet of Energy increases the domestic demand for high-tech equipment and also allows energy companies to act as solution providers based on the concept of the Internet of Energy, both in the domestic market and in the external market.

5. Load aggregator. Under the spread of distributed generation and generation based on renewable energy sources, the concept of energy system flexibility is becoming increasingly important. Flexibility is understood as the ability of the power system to maintain the balance of power in conditions of high volatility in power consumption and generation power (especially in the case of a high percentage of RES in the power system), compensating for emerging imbalances with sources of flexibility. In turn, demand management can be considered as a source of energy system flexibility [Demand management..., 2019; Brown et al., 2020]. According to estimates made by the Center for Strategic Research, about 30% of the power receiving devices of end consumers can be controlled. A significant part of this capacity is distributed among consumers of the retail market and cannot be used due to high transaction costs. This problem is solved by the concept of a load aggregator - an entity that sells flexibility in the wholesale market and generates this flexibility by managing many small consumers in the retail market. The schematic diagram of interaction for the load aggregator model is shown in Fig. 5.

Russia is also implementing a pilot project on demand management with the use of load aggregators: in 2019 decree № 287 of the Russian Government was approved. It defined the basics of new demand management mechanism functioning and introduced the concept of demand management aggregator – an organization combining the resources of retail consumers for providing services on demand control as a new type of services for system reliability.

Under the pilot project a consumer concludes a services contract on system reliability with JSC IPS/UPS TSO. The need to change the load is formed by JSC ATS based on the results of a double model calculation of the DAM (with and without unloading), after which the system operator instructs the aggregator to reduce consumption by a certain amount of capacity, and the aggregator distributes this volume among consumers who have concluded an agreement with it. After the load is confirmed, the payment is rendered: JSC IPS/UPS TSO pays for the aggregator services, whereas the aggregator pays for customer services.

The main effects of the implementation of demand management programs are both long-term and short-term:

- reduction of electricity costs for end consumers due to more efficient balancing and establishment of an equilibrium price in the day-ahead market by shifting and smoothing consumption peaks;
- substitution of flexible load for expensive and inefficient capacities in the wholesale market in the medium term;
- in the long term, reducing the need for investment in new generating and grid capacities to cover peak consumption [Demand Management.., 2019].

[Kuzmin, 2019] assumes that in order to fully unlock the potential of the load aggregator concept, it is necessary to develop intelligent metering systems that allow to collect data on energy consumption and efficiently process them using artificial intelligence technologies. In the study [Demand Management.., 2019] the list of technologies necessary for the successful operation of aggregators is supplemented

Table 4
Weighted average estimates of effects broken down by active consumer models

The effect of the spread of the active consumer model	Active consumer model				
	Basic active consumer model	Active energy complex/ microgrid	Energy cell	P2P model / internet energies	Load aggregator
Reducing the cost of purchasing electricity for end consumers	4.0	5.7	6.0	4.3	6.0
Reducing the equilibrium price of the DAM due to the shift and smoothing of consumption peaks	4.0	6.0	5.0	4.3	6.7
Substitution of flexible load for expensive and inefficient capacities in the wholesale market in the medium term	4.7	6.0	6.0	5.7	6.7
Reduced need for investment in new generation capacity to cover peak demand in the long term	3.0	4.7	5.0	4.7	5.7
Reduced need for investment in new grid capacity to cover peak demand in the long term	4.3	5.7	4.7	4.3	5.0
Reduced losses in networks due to optimization of flow routes	4.3	6.0	6.0	5.7	4.7
Reducing the volume of technological and commercial losses in low voltage networks	3.0	5.0	5.0	5.0	5.0
The most efficient integration of distributed and renewable energy generation	4.7	5.0	4.7	3.7	2.0
Reduce operating costs and improve power supply reliability due to predictive equipment analytics	3.0	6.0	6.0	4.7	3.0
Increased effectiveness of participation in demand management programs due to a deeper analysis of end-customer behavior patterns	5.0	6.0	6.0	6.0	5.3
Creation of additional revenue generation for electric power companies through the provision of system and support services	3.0	5.3	5.3	5.0	5.7
Creation of additional revenue generation for electric power companies by commercializing big data on energy consumption	4.3	5.3	5.7	5.3	4.7
Increasing the greenness of the energy system and reducing the share of CO_2 emissions	4.3	6.0	6.0	5.7	6.3

Source: compiled by the author.

by digital transactional solutions and industrial Internet of things technologies.

The big data collected by IMS allows to analyze the load profiles of a large array of users and identify devices with high potential as part of demand management.

High-precision comparative analysis of demand management participants makes it possible to build new price models based on determining prices for each group of consumers involved in demand management, thereby maximizing their benefits [Lin, Wang, 2011]. Incentive demand management programs allow the dispatcher to involve new participants, and IMS, in turn, greatly simplifies the verification of load reduction, which is especially important for monitoring the fulfillment of demand management duties in the private sector, since there are no sufficiently accurate models for assessing demand management potential on the side of retail consumers [Bergman et al., 2011].

Thus, the demand aggregator model is able to involve consumers without their own generation into active participation in the operation of the energy system and not only to reduce the cost of electricity but also earn money on the system services provision.

3. Research results

In order to verify the previously identified potential effects of the spread of active consumer models, in-depth semi-structured interviews were conducted with seven representatives of electric power companies.

Employees of electric power companies - energy sales, electric grid and generating companies were chosen as the object of the interview. Each of the respondents holds a leadership position and has:

- scientific interest in the field of digital technologies in the electric power industry;
- direct relation to the sphere of innovative development in the electric power industry.

Based on the results of the interview analysis, the effects of active consumer model distribution were confirmed and updated, and a questionnaire was developed for scoring the effects.

In order to measure the identified effects from the spread of active consumer models, the statements of the questionnaire were formulated. Respondents were asked to choose the degree of agreement with the statements given in the questionnaire. To measure the degree of agreement, a seven-point Likert scale was used, where 1 - "completely disagree", 4 - "do not know, agree or disagree", 7 - "strongly agree". The content of the questionnaires, as well as the weighted average assessments of the experts, broken down by models of the active consumer, are presented in Table 4.

Conducted interviews with subsequent questioning showed that the active energy complex / microgrid, energy cell, P2P model / Internet energy, as well as the load aggregator have the greatest potential.

The basic model of an active consumer received relatively low ratings from experts due to the complexity of implementing such a model in practice and the high level of expected transaction costs during its operation, which is consistent with the theoretical review.

The P2P model/internet energy received lower scores than microgrid and energy cell. Such an assessment may be due to a high degree of uncertainty in the cost of high-tech components necessary for the implementation of this model, which may adversely affect the achievement of positive effects from the Internet of Energy model deployment.

During the interview, some of the experts pointed out the similarity of the active energy complex/microgrid and energy cell models, while noting that the differences between these models are due to differences in the regulatory legal framework of the countries in which such models are applied. The experts also noted potential barriers to the implementation of active energy complex/microgrid models, due to the insufficiently high price of electricity purchased from the unified energy system for the consumer to make a decision to switch to electricity using the microgrid model, as well as a possible conflict of interest between the owners of enterprises and the owners of generating capacities located on the territory of the active energy complex.

Conclusion

The paper presents the results of the analysis of key technological trends in the electric power industry, as well as active consumer models that appear as a result of a change in the nature of interaction between consumers and energy companies due to the spread of new technologies.

A review of domestic and foreign literature made it possible to identify the main effects from the spread of distributed generation (including the use of renewable energy sources), electricity storage systems, intelligent electricity metering systems, and industry 4.0 digital technologies.

These technologies in themselves have a number of effects: reducing the cost of purchasing electricity for the end consumer, reducing investment in new generating and grid capacities, improving the reliability and quality of power supply, and reducing CO_2 emissions into the atmosphere. In addition, these technologies expand the range of opportunities for interaction between consumers and energy companies, thereby forming a new category of consumer - an active consumer.

A study of innovative models of interaction between consumers and energy companies showed that there are many ways to involve the consumer in an active participation in the process of production, distribution and consumption of electricity. Each of the models has different characteristics, requirements for the technologies used in this model, and effects both for consumers and energy companies, and for the market system of electricity and capacity trading as a whole.

As a further line of the research, we see a detailed study of the barriers to the spread of active consumer models identified by experts, as well as a study of the factors for the success of these models' implementation.

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The consumer behavior and the formation of value in the Russian market of wine products

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Abstract

The purpose of this article is to analyze consumer behavior and the formation of value proposition in the market of wine products. The analysis of sales of wine products, as well as the analysis of preferences in the choice of alcoholic beverages in Russia has been carried out. The analysis was based on a survey of 372 Russian consumers of wine products, as well as 47 wine companies from six Russian regions. The survey showed that the most valuable characteristics for wine producers and consumers are the following: taste and price, price-quality ratio, aesthetics (design and packaging), composition, brand, possibility to taste and country of production. At the same time, it is possible to distinguish a number of different features between the value for consumers and the formation of the value proposition wine companies and consumers distinguish. The results of this study were the conclusions that wine producers should consider in the formation of the value proposition: the appearance of packaging, product disclosure, discounts and promotions.
Keywords: wine industry, consumer behavior, value for the consumer, value formation by the producer, value map, wine sales in Russia.

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Introduction

In recent decades, one of the priority sectors in the Russian economy has become wine industry. Products of wineries are in high consumer demand, providing cash flow to the regional and federal budgets.

In the Soviet Union, there were more than 200 thousand hectares of vineyards. The anti-alcohol campaign of 1985-1987 caused enormous damage to the Soviet wine industry, led to a reduction in the area of vine plantations and a decline in production. The newest round of development in Russian winemaking occured only in the early 2000s, but the industry still needs significant investment and innovative development.

In the current conditions, Russian market is facing a number of unfavorable factors leading to a high level of uncertainty, dynamism and hostility, which requires companies to form a strategy that ensures long-term competitiveness and business success.

Wine production in Russia is only 7% of the total output of alcoholic beverages in volume terms (80% is beer, 8%

is vodka). Viticulture and winemaking is a rather expensive business with a longer investment cycle, higher capital intensity and a longer payback period (about 5 years from planting a vine to selling wine) than the production of vodka or beer. Nevertheless, a revival of winemaking can be expected, since, despite the pandemic and the decline in incomes of the population, a culture of alcohol consumption is developing in Russia. The preferences of Russians are shifting from strong drinks towards still (+3% in 2020) and sparkling (+4.1%) wines, as well as beer (+4.2%).

The analysis of wine sales in Russia shows the following situation. According to the Rosstat report (Table 1), 88.8 million decaliters (dL) of wine products were sold in the Russian Federation in 2020, excluding sparkling wines and champagne, which is 5.8% less than in 2019.

If we consider only wine, sales in the country, on the contrary, increased by 3% to 55 million dL. The volume of sales of sparkling wines and champagne amounted to 17.8 million dL, it increased by 4.1%.

Table 1

Sale of alcoholic beverages to the population of Russia

Product	2020		2019	
	Mln dL	% by 2019	Mln dL	% by 2019
Vodka and liquors	84.8	101.9	83.2	99.9
Cognac	11.8	98.3	12.0	104.3
Wine products (without sparkling wines and champagnes)	88.8	94.2	94.3	98.8
Including wine	55.0	103.0	53.4	102.3
sparkling wines and champagnes	17.8	104.1	17.1	101.2
Beer and beer drinks	751.1	104.2	721.8	98.5

Source: compiled by the author based on: Rosstat. Socio-economic situation in Russia, 2021: https://rosstat.gov.ru/compendium/document/50801.

Over the past two decades, Russian winemakers have faced a number of economic, social and political challenges. These include changing global patterns of production and consumption of wine products, growing competition, as well as tightening legal regulation. In addition, the industry is characterized by high barriers to entry and sophisticated consumers. This makes it relevant to study consumer behavior and create new value for consumers, which allows them to derive the greatest benefit from an unfavorable economic environment.

The purpose of this article is to study consumer behavior and the formation of a value proposition by wine companies in Russia.

1. Formation of customer value: a theoretical review

The formation of the value proposition concept began in the 1980s and was marked by the works of M. Bower and R. Garda [Bower, Garda, 1986]. Scientists introduced the concept of a value delivery system and introduced the concept of "differentiating benefits". According to the findings of the researchers, there is a difference between the traditional (physical) approach to the process of creating a product (physical process sequence), which includes only the stages of production and sale, and the value approach (through the value delivery system), which consists of the stages of selection, provision and communication of value.

An article written by M. Lanning and E. Michaels, McKinsey's consultants, [Lanning, Michaels, 1988] provided a more detailed analysis of the value delivery system. The value proposition consisted of several theses which answer the question: "Why should customers buy the company's products and services?" Lanning and Michaels pointed out that the main components of this concept are "benefit or advantage provided to a certain group of customers at a certain price at a certain level of costs." The researchers also gave a definition of consumer value, the key aspects of which were stated values (benefits provided) and the total cost of the product (total cost for a product). The work discussed in detail the previously mentioned stages of choosing, providing and communicating value (in particular, it was mentioned that at the stage of choosing a value proposition, customer needs are identified and value is positioned). In the work of [Lanning, Michaels, 1988] examples of successful value propositions were given, and such a tool as a value map was also mentioned for the first time. Of particular note is the fact that the article emphasized the importance of each segment on the value map - a topic that was ignored in the most subsequent work on value propositions.

Lanning's later work focused more on the managerial aspect. The author emphasized that the success of a value proposition depends not only on its choice, but also on "the thoroughness, originality and innovativeness with which it is presented and communicated."

Lanning's next work, co-authored with L. Phillips [Lanning, Phillips, 1992], revised the early concept of customer value, with an emphasis on identifying and generating a range of benefits that are of value to existing and potential users. This article emphasized the need to create value propositions in all key market segments that are in the focus of the company.

While some scholars have studied value propositions from a theoretical point of view, trying to clarify the concept and its elements, others have focused on works that are empirical in nature. Among such studies, one should note the work on the so-called value disciplines, the authors of which were prominent American scientists M. Tracy and F. Wiersema [Treacy, Wiersema, 1993]. It should be noted that the concepts of value disciplines and value propositions are interrelated, but not identical. The undeniable value of the work of Tracey and Wiersam lies in raising the general level of awareness of the above listed concepts in the management environment. The researchers noted that enterprises must choose one of three value disciplines (ways to provide a particular value to the consumer):

1) operational excellence: providing the consumer with a reliable product (or service), ensuring its delivery, cost-effective and with minimal inconvenience;
2) proximity to the consumer (customer intimacy): point segmentation of markets and adaptation of goods (or services) to meet specific consumer needs;
3) product leadership: offering the most modern (innovative) product (or service) to the end consumer, often carried out in the context of a dynamically developing marketing campaign (emphasis on the timing of the product, its design, etc.).

A year after the release of Tracey and Wiersam's work, the concept of value proposition has been further developed. In particular, it should be noted the popularization of value maps, the ideas of which were formulated earlier in McKinsey. Thus, in the work of American researchers from New York University A. Kambil, A. Ginsberg and M. Bloch [Kambil et al., 1996], the first definitions and examples of the use of the concepts of "value map" and "value frontier"). Under the value map, scientists understood a schematic representation of "the positions of companies in the same industry in terms of efficiency and costs for the client," and the value boundary was "the maximum possible efficiency for the company at a given cost (for the client) in the current conditions." This study also argued that high-growth companies often focus on the consumer rather than the product (or service) or technology, and thereby create a distinctive value proposition for their customers. Moreover, the authors assessed how customers perceive value at each of the four stages of interaction with a product (or service) - purchase (buy), use, transfer and co-creation of products and services. The interaction at the stage of co-creation of a product (or service) was subsequently refined, as a result of which two main types of this interaction were identified: when the client creates value together with the company (actually co-creates) and when the client combines the product and its additions, which, in turn creates value for it (integrates).

Further exploration of the value proposition concept is also associated with Lanning's name: in this work [Lanning, 1998] he suggested that enterprises define the key parameters of value propositions based on the experience of consumption and use of a product (or service) by customers. In Lanning's new definition of value proposition, the focus was on the considerations that a customer after consuming and using a product (or service), including those related to the price of the product (or service). To develop effective value propositions, the scientist advised companies to "become consumers" by conducting ethnographic research (studying consumers in the natural circumstances of everyday life, taking into account cultural and everyday characteristics).

Based on the ideas of Lanning, S. Smith and J. Wheeler developed the concept of focusing on the experience of consumption and use of a product (or service) in the formation of value propositions [Smith, Wheeler, 2002]. Scholars have argued that as organizations begin to aggregate customer experiences, it is necessary to strive to differentiate those experiences by creating memorable interactions—that is, branded customer experiences. It is this experience that is critical in shaping and delivering the best value proposition. The article emphasized the importance of a company's focus on customer experience design (i.e., managing the customer experience by analyzing how they interact with them) and delivering that experience (i.e., evaluating ways to achieve the outcome desired by customers) when defining the key characteristics of a value proposition.

The development of the value proposition concept in the early 2000s took place in several directions, among which the following can be distinguished:

1) further study of the forms and key elements of value propositions;
2) the study of value propositions in the context of the parties interested in this process (including the study of the process of joint value creation);
3) the study of social, environmental and ethical issues that arise in the formation of value propositions.

Let's take a closer look at each of these areas of research.

Within the framework of the first direction, the works of J. Anderson, J. Narus, V. Van Rossum on the forms of value propositions, as well as the works of T. Rintamaaki, H. Kuusela, L. Mitronen, J. Smith and M. Colgate on the components of the consumer values (customer value dimensions).

[Anderson et al., 2006] described a key shortcoming of the value proposition approach, which only lists what the company considers a customer benefit. In this case, according to scientists, the formation of the so-called brand assertion is not excluded, that is, a situation in which the claimed benefits can be useful, but not of value in solving a specific customer problem. The authors did not deny that the definition of favorable differences (favorable points of difference), that is, a comparative analysis of the company's advantages with competitors, can be one of the forms of value proposition. However, scientists pointed to the likelihood of the so-called presumption of value (value presumption) formation, that is, a situation in which all these advantages are presented as equally important for the client, although favorable differences may, on the contrary, have different values. The article proposed to form a value offer based on a resonating focus: a company needs to identify one or two competitive advantages of a product (or service) that have the highest value for selected customer segments, while the benefits offered may be different in these segments.

The study [Rintamaki et al., 2007], in turn, emphasized that the value proposition should include components that not only provide value to customers, but also ensure the achievement of the company's competitive advantages. The following was proposed as four main components of customer value used in the formation of a value proposition:

1) economic component (for example, saving electricity consumption);
2) functional component (for example, ease of use);
3) emotional component (for example, attractive design);
4) a symbolic component (for example, obtaining a certain status among the consumer's social circle).

The first two components often act as points of parity - associations that are common to all products or services of a certain type or several brands, and the last two components - as points of difference - unique brand associations that should be strong and supportive.

The authors of [Kozlenkova et al., 2014] specified the previously proposed components of consumer value and formulated them as follows:

1) functional value (functional / instrumental value) - the level to which the product is useful and allows the consumer to achieve the goals associated with its use;
2) empirical / hedonic value (experiential / hedonic value) - the level to which the product creates the corresponding experiences, feelings and emotions in the client;
3) symbolic / expressive value - the level to which customers determine the psychological significance of the product;
4) cost/sacrifice value - those costs and sacrifices that the consumer will associate with the use of the product.

Within the framework of the second line of research, it is necessary to single out works related to the concept of reciprocal value propositions. D. Ballantyne was one of the first scholars to formulate this idea [Ballantyne, 2003]. Building on earlier work that recognized the benefits of value propositions that imply value for both the firm and the customer, the scholar emphasized the two-way and reciprocal nature of value judgments. Further studies conducted by both Ballantyne and other authors confirmed the early conclusions of the scientist and supplemented them. In particular, N. Morgan in [Morgan, 2012] argued that if the participants in the value creation process recognize that their goals are complementary and convey this idea during negotiations, the value for both parties will thereby be enhanced. The value in this approach is not so much a strategy or a set of benefits for clients, but a comprehensive process in which the negotiation process plays an important role in creating value for each party.

Subsequently, the concept of mutual value propositions was transformed into the concept of co-created value propositions. This area was explored by such prominent scientists as S. Vargo and R. Lusch [Vargo, Lusch, 2004] who argued that value co-creation is a key component of the service-dominant business logic according to which any production of goods, services or hybrid products should be service-oriented. P. Frow and E. Payne [Payne, Frow, 2005] emphasized the exchange of benefits and sacrifices in the process of creating permanent relationships with clients; K. Kowalkowski et al. [Kowalkowski et al., 2012] suggested using practical observations in the formation of joint value propositions).

Separately, studies should be noted, the focus of which shifted towards a more thorough study of the stakeholders' influence on the formulated value proposition. This thesis is present in the writings of Lanning, who emphasizes that an enterprise must work with other stakeholders in the value chain to provide an appropriate value proposition for the main player - the customer [Lanning, 2003]. Ballantyne argued that during the process of intra-company integration of resources, interaction with a wide range of stakeholders is inevitable, which, in turn, makes it possible to emphasize their active participation in the formation of a value proposition [Ballantyne, 2003]. J. Mish and D. Scammon stated that enterprises need to formulate for themselves the widest possible range of goals and objectives and, accordingly, involve as many stakeholders as possible in the process of creating a value proposition [Mish, Scammon, 2010].

As part of the third area of research, the attention of scientists was focused on social, environmental and ethical issues related to the formation of a value proposition. One of the first works on this topic was written by J. Emerson [Emerson, 2003], and it dealt with the social and environmental aspects of value proposition formation, regardless of whether the organization that forms such an offer is commercial or non-commercial. This topic was further developed in the article [Spickett-Jones et al., 2004], which showed the importance of the ethical component of value propositions. M. Müller brought the problem of non-economic components in value propositions to a new level. He proposed to consider manufactured products and services from two points of view - in relation to the concept of sustainable development (the transition of society from an irrational way of using resources to a rational one) and to innovation (development of a tool to create innovative products that meet the needs of people and are favorable for the environment, the economy and society) [Müller, 2012]. S. Patala and a group of co-authors [Patala et al., 2016] finally formulated the concept of a sustainable value proposition: it was defined as "the promise of economic, environmental and social benefits that a firm offers to consumers and society as a whole, taking into account the receipt of short-term profits and the achievement of long-term sustainable development.

Modern sholars consider value propositions and its components through the prism of innovation and intrapreneurship (intra-company entrepreneurship). In such studies, the case study method is often used. In this regard, the work of J. Lindic and K. M. da Silva and [Lindic, Marques da Silva, 2011] who argued that the value proposition is "a catalyst for customer-centric innovation", should be noted. The study systematically examined the innovations created at Amazon. As a result, the authors decomposed the value proposition into five key elements: performance, ease of use, reliability, flexibility and the degree of emotionality (affectivity), thereby forming the concept of PERFA. However, it should be noted that a significant limitation of this work was that within the framework of the named article, a study was not conducted on the influence of the identified elements of the value proposition on each other, and the degree of relevance of these elements in various contexts was not determined (for example, within the product life cycle) or customer life cycle). Nevertheless, the work of da Silva and Lindich provides insight into how companies can unlock unique, innovative value propositions and create potential demand in untapped market niches.

The idea of developing tools for decomposing value propositions in order to stimulate organizations to improve their competitive positions can also be traced in the work of Payne and Frow [Payne, Frow, 2014]. Its value lies in two aspects. First, the authors carried out work to identify the key elements that affect the value proposition, using the example of a healthcare organization (hospitals). Secondly, the method formulated by scientists to determine the components of a value proposition was successfully applied within an organization from another field of activity (a large insurance and investment firm). Separately, it should be noted that the researchers included the concept of value-in-use in the developed methodology, thereby emphasizing not only the importance of learning in the process of improving value propositions, but also the interactive and recursive nature of such learning.

A deep analysis of the relationship between value propositions and the success of intra-company organizational formations of innovative activity that formulate them was carried out by a team of authors led by J. Covin [Covin et al., 2015]. After examining the data from almost one hundred and fifty corporate innovative enterprises, scholars came to the conclusion that the success of such structures depends on their ability to:

- Anticipate the needs of consumers in potential (target) markets for which the formulated value propositions may be of interest;
- adjust these value propositions as the enterprise evolves;
- use the full range of relevant knowledge available to the parent corporation.

According to the authors, in-house innovation entities whose value propositions showed moderate evolution were more successful than those, whose value propositions showed little or no evolution at all.

One of the latest works in which value propositions are viewed through the prism of service-dominant logic is the work of the team of authors led by P. Skaalen [Skålén et al., 2015]. Assuming that a value proposition in the context of service innovation is a combination of several different practices ("routine activities and evaluation systems used to integrate resources into value propositions") and resources, the researchers further identified ten key practices and formed them into three groups: provision practices, a representational practices group, management and organizational practices group. Moreover, the article argues that the process of creating service innovations can be equated with creating new value propositions by evolving existing practices, creating new practices and/or resources and integrating them in new ways. The value of the work also lies in the presence of a classification of service innovations. Thus, the innovations themselves were divided into adaptation, resource, methodological (based on the practices mentioned above) and combined. Thus, the authors emphasize the fact that successful service innovations are not only about the availability of the necessary practices and resources, but also how they are integrated into the value proposition formulated by the company.

Thus, despite the fact that the concept of a value proposition is at the center of attention of the academic community, research on this issue has often been carried out in different directions, which has given rise to a large number of interpretations of this concept. In this regard, the research question of this study is the understanding of value by Russian wine companies, as well as how their creation of consumer value corresponds to the preferences of Russian consumers.

2. Research methodology

To answer the research question, the preferences of Russian consumers in the wine market were analyzed, as well as the understanding of key elements and the formation of consumer value by companies in wine industry.

The study was conducted between January and May 2021. Electronic questionnaires were sent out to collect consumer opinions. Responses were received from 372 Russian consumers of wine products from 12 Russian regions. Characteristics of consumers are presented in Table 2.

In-depth interviews based on a semi-structured guide were used to collect the opinions of representatives of wine companies regarding key components and value creation. Empirical analysis included several stages: guide development, interviews, content analysis of the data obtained.

At the first stage, based on the results of the theoretical analysis, a guide was developed for conducting in-depth interviews. The purpose of the interview was to collect opinions on building value for customers in their companies. The protocol included questions that related to the definition of value for customers and value-oriented management, as well as the formation of a value proposition in the company.

At the second stage, in-depth interviews were conducted with 47 managers of Russian wine companies representing customer service, sales, innovation, strategic management,

Table 2
Characteristics of consumers in the sample

	Number of respondents in the sample (people)	Percentage of respondents (%)
Women	197	53
Men	175	47
Age of respondents		
18–30	67	18
31–45	126	34
46–60	134	36
60+	45	12
Education		
Higher	219	59
Secondary professional	123	33
Secondary	30	8
Average monthly income		
Up to 50 000 rub	115	31
50 000–100 000 rub	101	27
100 000–200 000 rub	93	25
200 000–300 000 rub	48	13
More than 300 000 rub	15	4
Type of employment		
employee, specialist	104	28
management staff	45	12
entreprener	60	16
service sector	45	12
worker, driver	48	13
housewife	33	9
pensioneer	22	6
other	15	4
Place of residence		
Federal cities	108	29
cities with a population of more than 1 million people	82	22
cities with a population of 500–999 thousand people	63	17
cities with a population of 300–499 thousand people	41	11
cities with a population of 100–299 thousand people	33	9
cities with a population of 100 thousand people	26	7
Rural settlement	19	5

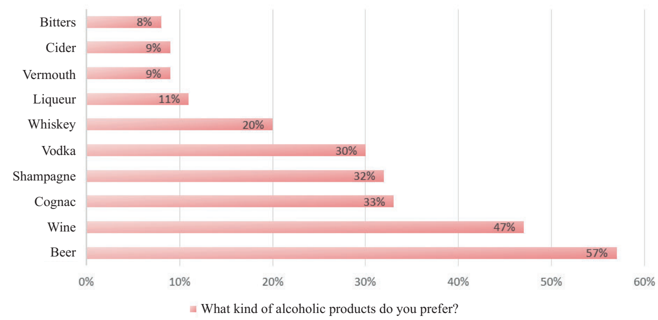
Source: compiled by the author.

Table 3
Geographic distribution of the sample wineries

	Number of sample companies	Share of companies in the sample (%)
Region		
Crimea (Republic of Crimea and Sebastopol)	11	23
Republic of Dagestan	8	17
Stavropol Territory	9	19
Rostov Region	7	15
Kabardino-Balkar Republic	8	17
Volgograd Region	4	9
Company size		
Small and Medium Business Companies	30	63
Major companies	17	37
Company age		
Less than 5 years old	8	16
5–15 years old	10	22
15–25 years old	15	32
More than 25 years old	14	30

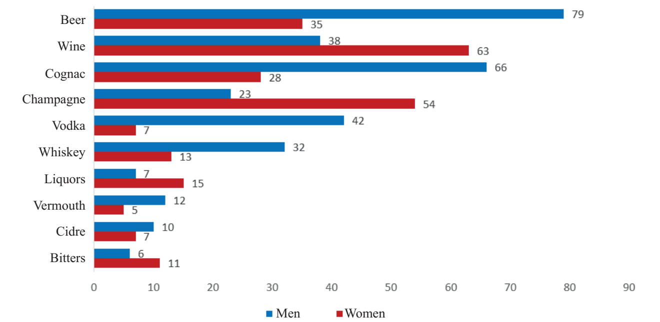
Source: compiled by the author.

Fig. 1. Respondents' preference when choosing alcoholic beverages (% of respondents)



Source: compiled by the author.

Fig. 2. Preference of respondents when choosing alcoholic beverages among men and women (% of respondents)



Source: compiled by the author.

marketing, brand managers, etc. The companies are located in six Russian regions (Table 3). The average interview time was about 30 minutes.

3. Research results. The value of wine to consumers

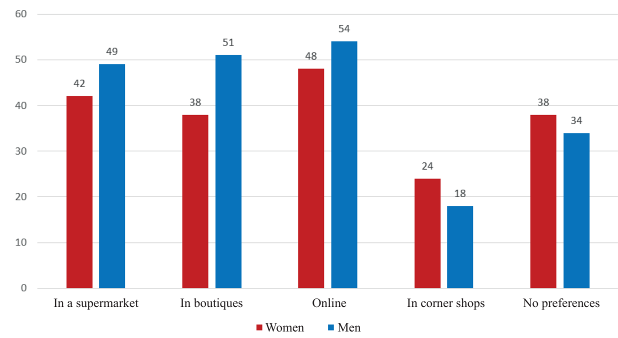
The analysis of preferences in the choice of alcoholic beverages shows that Russians prefer such drinks as beer (57%) and wine (47%) (Fig. 1).

At the same time, men and women have different preferences in the choice of drinks (Fig. 2).

Also, most Russians prefer online wine purchases (Fig. 3). In the second place in popularity there is shopping in the supermarket and special boutiques. It is interesting that a third of the respondents have no preferences.

The purposes of buying wine by the respondents are presented in Fig. 4.

Fig. 3. Respondents' choice of how to buy wine (% of respondents)



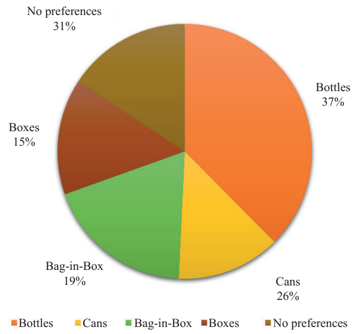
Source: compiled by the author.

Fig. 4. Purposes of wine purchase by respondents (% of respondents)

Source: compiled by the author.

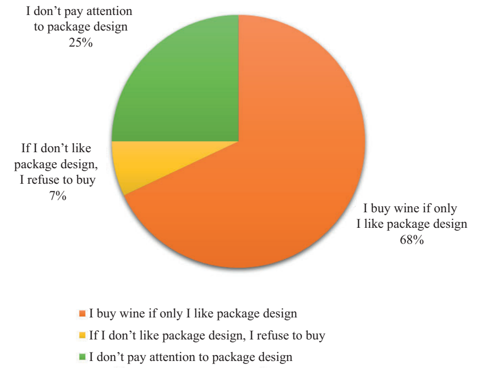
The survey showed that the most popular purposes for buying wine for both men and women are meeting with friends, guests, visiting a restaurant or cafe.

Fig. 5. Respondents' preferences for wine packaging (% of respondents)



Source: compiled by the author.

Fig. 6. Attitude towards wine packaging (% of respondents)



Source: compiled by the author.

As you can easily see, most of the purposes of buying wine were related not to personal/family consumption, but to consumption of wine in a company (meeting with friends, guests, going out of town, as a gift, corporate party, on a special occasion).

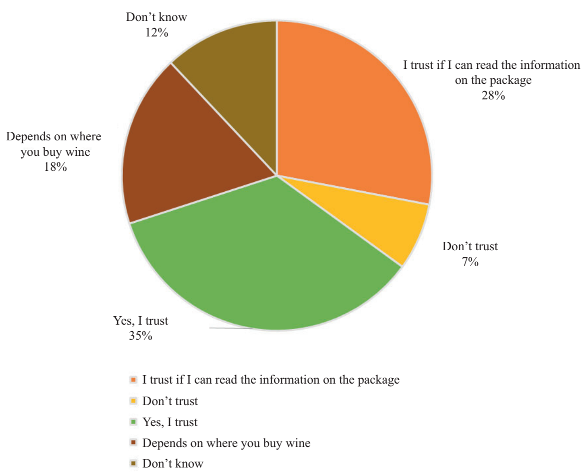
It can be recalled that when promoting wine, the main emphasis is on the quality of the wine itself, aroma, vineyards, country of origin.

In our opinion, when promoting the wine market, it is necessary to use a different creative concept, focusing on the collective consumption, celebration, meeting, fun, relaxation.

Consumer preferences in packaging are shown in fig. 5. Thus, the vast majority of respondents prefer bottles as packaging. In the second place in terms of preference there are waterskin bags placed in cardboard packages with a capacity of up to several liters – Bag-in-Box. According to respondents, this packaging has a lot of advantages: firstly, the Bag-in-Box does not break and is very convenient for transportation, and secondly, those who bought wine in such packaging do not need to look for a corkscrew. The "barrel" has a bottling valve with a one-way valve that does not allow air to enter the bag, so even when open, the wine does not lose its properties for at least three months. With this tap, wine can be poured into a decanter or directly into a glass. It is aesthetically pleasing and convenient, besides, buying wine in a package, you can win in price. At the same time, the quality level of bottled wine and wine in Bag-in-Box packaging is usually identical.

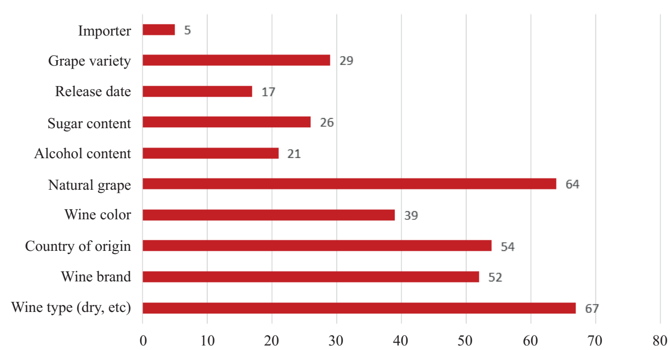
The attitude to the packaging of wine is shown in fig. 6. According to the survey, the vast majority of respondents make a purchase, evaluating not only the quality of wine, but also its packaging. The next question was devoted to trust in the information printed on the packaging of wine (Fig. 7). According to the survey, the majority of respondents trust the information on the packaging (35%) or trust if they can read the information (28%). For 18% of consumers, trust is associated with the place where wine is bought. The remaining respondents either do not trust this information (7%) or find it difficult to answer this question (12%).Also, as the information that the respondent refers to when buying wine, they mentioned the storage temperature, the place of bottling, and the design of the package.

Fig. 7. Attitude of respondents to the information indicated on the packaging of wine (% of respondents)



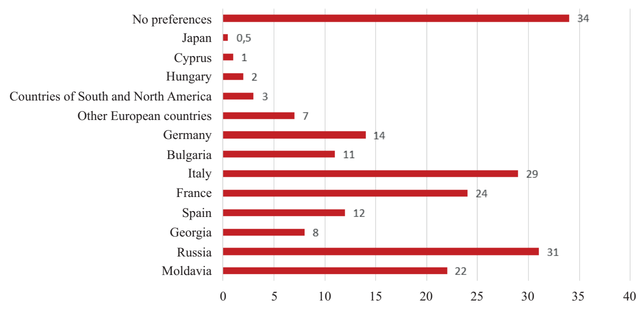
Source: compiled by the author.

Fig. 8. Characteristics of wine that stimulate its purchase (% of respondents)



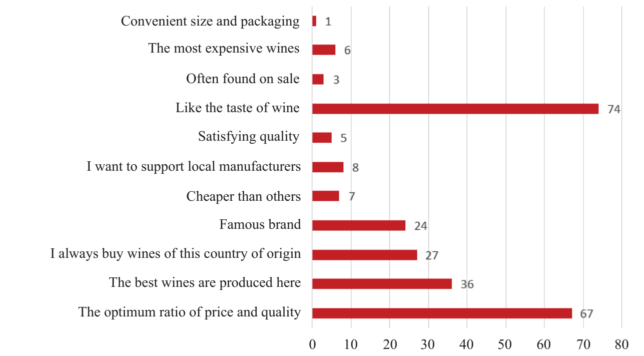
Source: compiled by the author.

Fig. 9. Purchasing preferences by country of wine production (% of respondents)



Source: compiled by the author.

Fig. 10. Reasons for choosing wine (% of respondents)



Source: compiled by the author.

The following are the characteristics of wine that motivate buyers to buy it (Fig. 8). According to the survey, the most important characteristics when buying wine are type (67%) and brand (52%) of wine, country of origin (54%), naturalness (64%) and color (39%).

Consumer preferences by country of wine production are shown in Fig. 9. Currently, wines from Russia (31%), Italy (29%), France (24%), Moldova (22%) are the most popular among consumers, since there is an opinion that these countries have the highest quality budget-friendly wine. Note, that from time to time preferences in relation to the countries of wine production change. Thus, Georgian wines were previously considered to be of the highest quality, but the massive falsification of these wines has changed the opinion of consumers for the worse.

The lesser popularity of European and other foreign wines is due not to their poor quality, but to a higher price and the fact that the wines of these countries are less represented on the market, they are more difficult to find.

It should be noted that there is a fairly high percentage of those who have no preference for the country of wine production. Apparently, a third of buyers are guided by other factors when choosing wine.

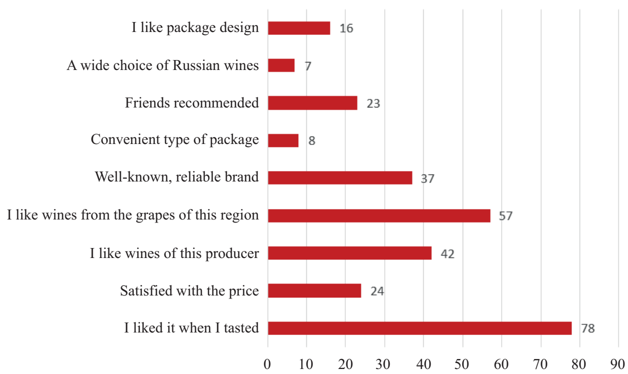
Therefore, the reasons for choosing wine are analyzed below (Fig. 10). The most significant characteristics when choosing a wine are: taste (74%), optimal value for money (67%), proven quality (36%), brand awareness (24%).

Next, the reasons for choosing wine from Russian producers were analyzed (Fig. 11). The reasons for the positive attitude towards wine of Russian producers lie primarily in the fact that almost 78% of consumers of Russian wines are satisfied with its taste. 57% of respondents like wines made from the grapes of the respective region. About a quarter of consumers (24%) are satisfied with its price, and 42% of respondents trust the manufacturer. A fifth of respondents noted that they are comfortable with the volume of packaging (8%) and its design (16%), which indicates the need to pay attention to the quality of not only the wine itself, but also its packaging.

Consumer preferences by a type of wine are shown in Fig. 12.

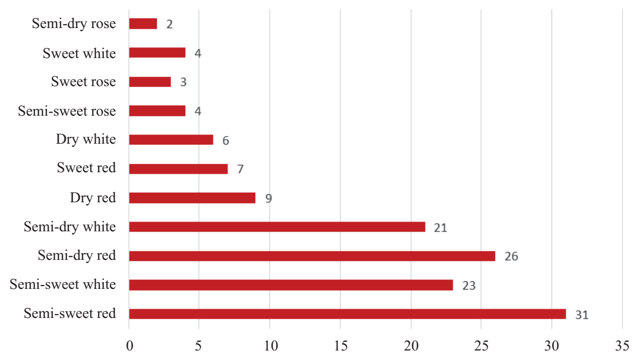
An analysis of consumer preferences shows that the group of rosé wines enjoys very low popularity in the market, so it should be produced in very limited volumes. The most popular is red semi-sweet wine. Perhaps these preferences correlate more with the presence

Fig. 11. Reasons for choosing wine from Russian producers (% of respondents)



Source: compiled by the author.

Fig. 12. Consumer preferences by type of wine (% of respondents)



Source: compiled by the author.

of this wine on the market than with the taste preferences of consumers. However, it can be unequivocally stated that semi-sweet and semi-dry wines are more preferable than dry ones, and red wines are more popular than white ones in any position.

4. Formation of the value proposition by Russian wine producers

Next, it was investigated how consumer preferences in choosing wine correlate with the formation of a value proposition by Russian wine producers.

Respondents' answers in the analysis of value creation tools are presented in Table 4.

According to the respondents, the most significant value creation tools are quality, recognition and customer focus. At the same time, such tools as brand uniqueness are almost never used in the practice of Russian companies, which can be explained by the insufficient level of Russian personnel's knowledge of the entire spectrum of creating a value proposition, and in particular, its most complex tools.

When asked about creating value together with their staff, most Russian companies admitted that they rarely involve

Table 4
Customer value proposition tools

Research	Examples of respondents' answers	Frequencies of mention	
		unit.	%
Product/Service improvement			
Quality	Quality is a fundamental element in value creation; the consumer appreciates high-quality goods; we check the quality on ourselves - we use the products and eliminate the shortcomings	14	30.1
Range	A wide range (large product line) allows you to find an individualized approach to the client.	4	8.7
Uniqueness	We are creating a product that is not yet developed on the Russian market; formation of an order specifically for the client	2	4.7
Product price reduction	By reducing the price of goods, the contractor increases his chances of winning in the competitive purchase; discounts, promotions for goods are in great demand among buyers; we cannot talk about price reductions, but we try to keep them within reasonable limits	3	6.9
Service improvement			
Ease of choice	A wide range, knowledge of proven brands significantly reduces the time to determine the choice	1	2.6
Risk reduction	Absence and minimization of abnormal spoilage and in rare cases of a low-quality batch - a complete replacement for a quality supply	1	2.3
Ease of purchase	The representation of the product in most retail chains affects recognition, increases sales; with the opening of sales via the Internet, the convenience of purchasing wine has increased significantly	2	4.7
Ease of use	Simplicity of technology, easy adaptation to it; the value of our products and services lies in the simplicity and easily assessable financial result	1	2.1
Brand formation			
Uniqueness	Uniquness of brand positioning and our company on the whole	1	2.1
Acknowledgment	Brand recognition; we are professionals in our field, and we have good references from relevant companies that apply to us	7	14.2
Stuff professionalism	Employees must be professionals	3	5.4
Relationship	Setting up a long-term relationship with the client; relationship with the client - above all; they need to be properly formed, maintained. Their loyalty and affection need to be increased.	2	3.4
Customer-oriented approach	The company must be able to attract customers, hear them, provide feedback	5	10.2
Personal qualities	The personal qualities of the staff sometimes play a decisive role, influence the choice of the client	1	2.6

Source: compiled by the author.

staff in this process. In foreign companies, on the contrary, personnel is one of the key sources of value proposition formation.

When asked about co-creating value with customers, most companies admitted that they involve customers whenever possible, using mostly questionnaires and surveys that help learn about customer preferences, desires, and satisfaction. It is important to note that a greater variety of tools and methods of interaction with consumers is found in foreign companies. However, in recent years, Russian companies have increasingly focused on business development through interaction with customers.

At the same time, in the work of companies involving customers in the joint creation of value, the tools described in Table 5 are used more often.

5. Conclusions

Analyzing the signs of a successful value proposition for customers from the point of view of researchers and practitioners, it is also possible to identify differences, they are presented in Table. 6.

Analyzing the common and different features of a successful value proposition identified among wine producers and consumers, it can be noted that the main features of a successful value proposition for both buyers and producers are taste and price, as well as quality, price-quality ratio, aesthetics (design and packaging), the composition of the wine (most buyers carefully study the composition indicated on the packaging), the brand, the possibility of tasting, and the country of origin.

Table 5
Tools to engage customers in value co-creation

Research	Examples of respondent's answers	Frequencies of mention	
		unit.	%
Feedback: the consumer fills in a questionnaire developed by the company, the consumer writes a review on the Internet, etc.	Questionnaires, online surveys, reading consumer reviews; the opinion of consumers has always been important to us, therefore, when creating a value proposition, in most cases we interact with customers (surveys, reviews, wishes); each client can call us at the phone number listed on the site, as well as at each retail outlet; questionnaires, online surveys, ratings of unscrupulous suppliers	19	40.7
Co-production is characterized by the participation of the consumer in the joint creation of value with the company at the final stages of creating a service (service consumption)	We involve clients in the process of discussing prepared reports and memorandums, adjust our own opinion and conclusions based on the client's comments; collaborative development of a product that would meet the needs of this particular customer contributes to the creation of a value proposition	3	7.0
Service innovation	Use of innovations, creation of integrated offers, expansion of services; quality service is the basis of our company, we pay close attention to training our employees in customer interaction techniques	2	4.7
Customization	The client is first offered a range of planned values, after which his opinion is listened to and something is added depending on the need; each problem is usually unique, and its solution is applicable to a specific object with given requirements	4	8.1
The interaction of the consumer with the company, as well as his participation in promotions / events initiated by both the company and the consumer himself	Participation of consumers in various events within the framework of event-marketing, promotions; companies willingly participate in our research, which we regularly conduct and then publish the results; monthly we carry out a large number of promotions, including digital campaigns, which involve more and more consumers and motivate them to try and buy our products more often	10	20.9
Virtual brand community	We have official accounts on social networks, where communication takes place mainly with potential future employees, but nevertheless their work, I think, can be called effective; in addition to the virtual reception, there are pages on social networks, where work is also being done to track complaints and suggestions; there are groups in social networks, as well as "crops" on the forums visited by the target audience	9	18.6

Source: compiled by the author.

Table 6
Common and differing signs of a good value proposition highlighted among wine producers and consumers

Elements	Consumers	Producers
General	Tastiness	
	Price	
	Quality	
	Ratio "price-quality"	
	Aesthetics (design and package)	
	Ingredients	
	Brand	
	Degustation	
	Country of origin	
Different	–	Range
	Discounts, promotions for temporary price reductions	–
	–	product visibility and merchandising
	Purpose of purchase (reason for consumption)	–
	–	Unique selling points, USP
	–	Customer loyalty

Source: compiled by the author.

Signs such as discounts, promotions for temporary price reductions and the purpose of the purchase (reason for consumption) are important only for the consumer, who is interested in them: for example, buying one bottle, get the second as a gift or at half price. The manufacturer, on the contrary, does not like discounts and promotions, since a decrease in the initial cost of the goods, although it attracts buyers, negatively affects the brand image and occurs due to savings in the budget for advertising and promotion.

For the manufacturer, the assortment is important, allowing to differentiate and attract consumers with different tastes and preferences. Product display and a unique selling proposition allow you to offer the consumer those characteristics of the product, thanks to which it will differ from its competitors in the same category, which will allow you to build effective communications with the consumer and form their loyalty.

Conclusion

The past 30 years have seen an increase in the amount and complexity of academic and professional research focusing on customer value generation, reflecting the interest of researchers, manufacturers, and consumers in product value proposition strategies. A value proposition refers to the value a manufacturer promises to deliver to consumers if they decide to buy its product, it is also a declaration of intent or statement that introduces consumers to a company's brand by telling them what the company is, how it works and why it deserves their attention.

A successful value proposition must be compelling and help turn a potential customer into a paying customer. All effective value propositions are easy to understand and demonstrate concrete results for the consumer.

The wine market is considered difficult for consumers to make decisions, and wine marketing is informational. Forming a successful wine value proposition allows the producer to find out the distinctive features of his product from the products of competitors and inform the consumer about the value within a short period of time.

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Identification of the national innovation system in a globalized environment

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Abstract

The activation of innovation processes always requires the presence of an appropriate enabling environment - an effective national innovation system (NIS), which determines the country's ability to generate and implement various kinds of innovations. However, the formation of a full-fledged country's innovation system is quite difficult, at least for two reasons: the presence of purely national features of the functioning of the main agents of change, as well as the specifics of the modern world, when many important processes for innovation go beyond individual countries, forming a globalized environment, the presence and the specifics of which determine the potential and strategic directions for the further development of each NIS. The scientific and methodological approach proposed in the paper is generally based on the hypothesis of the expediency of regulating a particular national innovation system development, taking into account its belonging to a certain basic type, which determines the specific features of development. For its implementation, the methods of genetic algorithms, cluster analysis, and neural network training were used. Within the framework of the study, four basic types of NIS were identified and qualitatively interpreted, which have characteristic features in the context of the quadruple helix concept of development. To identify the national innovation system, a neural network, which simplifies the modeling of its development, was built. As a demonstration of the additional possibilities of the toolkit, four supranational associations of countries have been identified and analyzed. The practical significance of the results lies in the possibility of conducting variable analytical and predictive studies in the course of substantiating the optimal directions for the further development of the national innovation system in terms of global and cluster trends.

Keywords: national innovation system, genetic algorithm, clustering, neural network model, basic type, regulation, modeling.

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Introduction

The effectiveness of any national innovation system is largely due to the state of its four main complexes: scientific and educational (SE), state-political (SP), production and economic (PE) and socio-cultural (SC), which form a single ecosystem within the framework of the concept of the quadruple helix of development [Carayannis, Grigoroudis, 2016]. A change in the functioning parameters of any of them as a result of national policies, of course, affects both the state of others and the overall result, since mutualism takes place - a situation in which the effectiveness of interaction is important both for joint functioning and separately. At the same time, the interdependent development of NIS complexes is accompanied by the formation of a set of multilateral adaptations (co-adaptations) that optimize these stable interactions.

The ontological complexity of the problem of increasing the efficiency of the NIS is exacerbated by the fact that in the modern integrated world, many processes important for innovation go beyond the boundaries of individual countries, forming a globalized environment, the presence and specifics of which determine the potential and strategic directions for the further development of each individual system. That is, while maintaining a significant degree of independence, the NIS of each country evolves not only within this environment, but also along with it. Thus, the hypothesis about the existence of several characteristic basic types (images) of national innovation systems is updated, which can be identified and to which, with a certain degree of approximation, all innovation systems of national economies in the world can be attributed. At the same time, each such type has its own stable and unique features which to a large extent determine the behavior parameters and capabilities of the corresponding NIS. Based on this, the development of each individual national innovation system, on the one hand, is multi-vector due to its own identity, and on the other hand, it can be significantly limited by intertype features.

Taking into account the above mentioned, any impact on the development of the national innovation system should take into account not only the features of the transformation of its constituent complexes but also the characteristic features of the corresponding basic type. They are also transformed in time and space in a specific way due to the influence of geographical, economic, sociocultural and other factors. It is the consideration of type affiliation that makes it possible to correctly determine the strategic directions for the development of the NIS and improve the efficiency of its regulation.

The study of national innovation systems has been a popular trend in recent years. Thus, the founders of the NIS concept [Freeman, 1982; Metcalfe et al., 1988; Lundvall, 2007] believe that each such system is unique and inimitable, despite a number of universal features. A similar point of view is shared by researchers who focus more on national specifics and its dynamics (see, for example, [Datta et al., 2019]). In addition, the focus of research has extended to other levels, including subnational (Silicon Valley) [Saxenian, 1994], sectoral [Malerba et al., 2004], technological [Carlsson, Jacobsson, 1997], regional [Asheim et al. , 2004], supranational [Jackson, 2014]. There are also studies that identify clusters of supranational innovation systems that go beyond administrative boundaries [Proksch et al., 2019]. Of no less interest in scientific and practical terms are taxonomies [Godinho et al., 2005; Balzat, Pyka, 2006]: the first paper analyzes 69 countries with different regions of location and economic development, the second one analyzes the international features of the NIS of eighteen advanced high-tech countries of the Organization for Economic Cooperation and Development. The approaches that form the conceptual basis for global innovation systems should be singled out separately [Binz, Truffer, 2017].

In general, the analysis of a number of works in this area proves that, despite the differences in the approaches and tools of different authors, the hypothesis of the existence of basic types of innovation systems is objectively justified and confirmed by empirical observations.

Paying tribute to the results of existing studies on the taxonomy of national innovation systems, due to the complexity, comprehensiveness and breadth of problem understanding, the theoretical and practical aspects of solving this issue are not universal, since in most cases they are limited by the specifics of researchers' goal setting. In this regard, the purpose of this work is to propose a scientific approach to the typology of national innovation systems, which contributes to the solution of a number of problems related to the identification of national innovation systems, clarification of the composition of their basic types, analysis of functioning supranational formations for type affiliation, as well as development modeling.

1. Description of the research methodology

Based on the stated goal and expected results, the research methodology involves the use of a number of economic and mathematical methods that, according to the initial set of indicators, allow:

1) to establish the similarity of national innovation systems and form stable clusters that correspond to certain types of NIS, which are considered as basic (parent);

2) to develop tools for classifying new objects of research to the corresponding types of NIS.

In a general approximation, the process of recognizing the basic types of the national innovation system can be represented as follows (for more details, see [Kravchenko, 2019; Kravchenko, Zanizdra, 2019]):

1.1) substantiation of the classification features of the national innovation system (based on the concept of the quadruple helix of development);

1.2) formation of a representative sample of indicators (the study is based on databases of world rankings for different years: the Global Innovation Index, the Global Competitiveness Index, the Human Development Index). Valdai and the All-Russian Public Opinion Research Center), data from the UNESCO Institute for Statistics, the Travel Weather Averages Internet resource, the International Energy Agency, the World Bank's Energy Sector Management Assistance Program, etc. The initial sample consists of 136 countries whose national innovation system parameters characterize 148 qualitative and quantitative indicators in the context of four classification features: SE, SP, PE and SC);

1.3) the normalization of the sampling parameters (for further correct comparisons) was carried out according to the rule: a higher value of the standardized indicator means a more efficient functioning of the national innovation system. Thus, the indicators were brought into the range [0, 1] (for the subsequent construction of a neural network with a binary data type);

1.4) each analyzed indicator received a number based on classification group (attribute) it belongs to. Further, the resulting series was used as an objective function in the selection of the most significant countries for the formation of clusters (the method of genetic algorithms was applied). That is, an inverse problem was solved: with a certain division of objects into groups, indicators were selected that had the greatest impact on this division. Thus, the primary matrix has been streamlined (reduced to 95 countries);

1.5) cluster analysis of a truncated/optimized sample (using the Ward method). The measure of distance is the square of the Euclidean distance. The number of clusters was refined using the quality functional - the sum of the squared distances to the center of the clusters. At the same time, when divided into four clusters, the functional amounted to 255, into five - 235, into six - 254.

To solve the problem of assigning new objects to the basic types of national innovation systems, a neural network was built (for more details, see [Kravchenko, Zanizdra, 2019]). The algorithm for its formation is as follows:

2.1) collection, analysis and standardization of input data (the previously described sample of 136 countries and 148 indicators was used);

2.2) choice of architecture and definition of the structure of the neural network (multilayer perceptron with one hidden layer: 148-60-5);

2.3) training of the neural network (70% of the primary parameters were used, optimized by the methods of genetic algorithms, the definition of the training set - 100% result);

Table 1
Representatives of NIS's basic types

NIS of type A Developed countries with predominantly inclusive institutions	
1. Australia	14. The Netherlands
2. Austria	15. New Zealand
3. Belgium	16. Norway
4. UK	17. The USA
5. Germany	18. Finland
6. Denmark	19. France
7. Israel	20. Switzerland
8. Ireland	21. Sweden
9. Iceland	22. Estonia
10. Canada	23. Japan
11. Republic of Korea	
12. Luxembourg	
13. Malta	

NIS of type B Developing countries with mixed extractive-inclusive institutions with a strongly pronounced socio-cultural component (mainly Muslim and Buddhist-Hindu types)	
1. Azerbaijan	11. Malaysia
2. Bahrain	12. Oman
3. Butane	13. Panama
4. Brunei Darussalam	14. Rwanda
5. India	15. Saudi Arabia
6. Indonesia	16. Tajikistan
7. Jordan	17. Thailand
8. China	18. Chile
9. Kuwait	
10. Mauritius	

NIS of type C Developed and developing countries with mixed extractive-inclusive institutions with a strongly pronounced informal component (including the post-Soviet type)	
1. Albania	15. Mongolia
2. Armenia	16. Poland
3. Bulgaria	17. Portugal
4. Bosnia and Herzegovina	18. Russian Federation
5. Hungary	19. Romania
6. Greece	20. Serbia
7. Georgia	21. Slovakia
8. Spain	22. Slovenia
9. Italy	23. Ukraine
10. Kazakhstan	24. Croatia
11. Cyprus	25. Montenegro
12. Latvia	26. Czech Republic
13. Lithuania	
14. Moldova	

NIS of type D Developing countries with predominantly extractive institutions	
1. Algeria	33. Malawi
2. Argentina	34. Liberia
3. Bangladesh	35. Lebanon
4. Benin	36. Mauritania
5. Botswana	37. Mali
6. Brazil	38. Morocco
7. Burundi	39. Mexico
8. Venezuela	40. Mozambique
9. Vietnam	41. Namibia
10. Haiti	42. Nepal
11. Gambia	43. Nigeria
12. Ghana	44. Nicaragua
13. Guatemala	45. Pakistan
14. Guinea	46. Paraguay
15. Honduras	47. Peru
16. Dominican Republic	48. Republic of Chad
17. Egypt	49. Salvador
18. Zambia	50. Seychelles
19. Zimbabwe	51. Senegal
20. Iran	52. Sierra Leone
21. Yemen	53. Tanzania
22. Cape Verde	54. Trinidad and Tobago
23. Cambodia	55. Tunisia
24. Cameroon	56. Turkey
25. Kenya	57. Uganda
26. Kyrgyzstan	58. Uruguay
27. Colombia	59. Philippines
28. Congo	60. Sri Lanka
29. Costa Rica	61. Ecuador
30. Laos	62. Eswatini
31. Lesotho	63. Ethiopia
32. Madagascar	64. South Africa
	65. Jamaica

Source: compiled by the author.

2.4) testing and verification of the neural network (breakdown of the initial data: 15% for testing and 15% for verification, while the definition of the test sample corresponds to 92.9% of the result, the verification sample - 85.7%, which indicates a fairly high quality of network formation).

2. Theoretical and calculated parts

Cluster analysis of an optimized sample of 95 countries with different geographical locations and levels of development of national innovation systems (scientific-educational, industrial-economic, state-political and socio-cultural complexes characterized by 148 indicators) made it possible to identify five clusters. However, an in-depth analysis of their composition showed that one of them, the smallest one, includes countries in which high performance indicators are achieved through rental income. Therefore, this cluster (United Arab Emirates, Hong Kong SAR (China), Singapore, Qatar) was excluded from the taxonomy in the study. Thus, in the end, four basic types of national innovation systems were identified.

Using the constructed neural network for countries previously recognized as insignificant for clustering and screened out by the genetic algorithms method, the basic type of NIS was established. Full information on the grouping of 132 countries is presented in Table 1.

The study analyzes the degree of development/efficiency of the national innovation system in terms of the above four elements of the development spiral. In this regard, further, in order to objectify the analysis of the achievements of different countries, the generalized results of three world rankings were additionally used: the Global Innovation Index (GII), the Global Competitiveness Index (GCI), and the Human Development Index (HDI). The data of these ratings are adapted to the respective samples of countries: they are standardized and summarized into an integral indicator (Ni) for each country (Table 2):

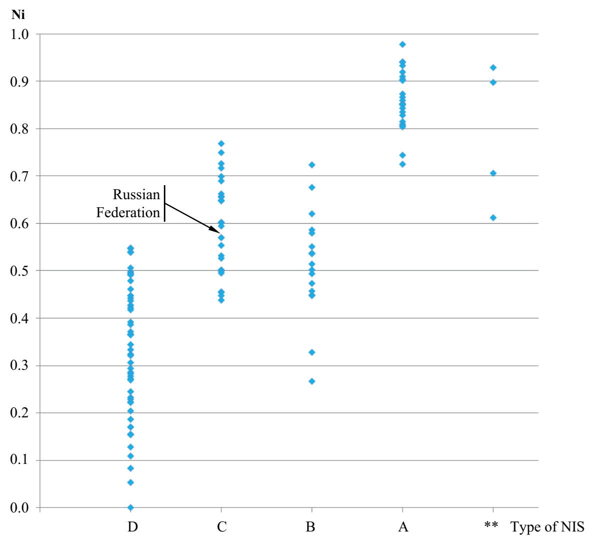
$$N_i = \sqrt[3]{GII_i^* \times GCI_i^* \times HDI_i^*},$$

where GII^*_i is the standardized value of the GII rating for the i-th country, GCI^*_i is the standardized value of the GCI-rating for the i-th country, HDI^*_i is the standardized value of the HDI-rating for the i-th country.

This approach is designed to provide a certain balance in assessing the achievements of different countries in the field of innovation, paying attention not only to the effectiveness of efforts in this direction, but also to the degree of public satisfaction with the achieved results.

The measure of the validity of using the integral indicator (N_i) was confirmed by the closeness of the relationship between it and the values of the "Most Innovative Countries in the World" rating (according to Bloomberg) using the Spearman rank correlation coefficient in 60 countries. This non-parametric method characterizes relationships between variables measured by a rank scale (the sample size is determined by the availability of data published by the specified agency). Taking into account the above mentioned and the fact that the analyzed sample includes more than 130 countries, and individual ratings (for example, Bloomberg) are less, further in the comparative analysis of economies the results of the integral indicator (N_i). were mainly used. A graphical interpretation of the results of clustering and ranking countries based on it is shown in Fig. 1.

Fig. 1. Graphical interpretation
of the countries ranking results by NIS's basic types



Notes: 1. Countries are ranked according to the indicator (N_i) as of 2020.

2. ** – rich countries with rental economy (represented for reference only).

Source: developed by the author.

Summarizing the information obtained, we can draw general conclusions:

- within the selected types of NIS (except for countries excluded from the typology), there is a close homogeneity of economies;
- the top third of the rating is mainly represented by developed countries of type A, which are "supported" from below by the leaders of the NIS countries of type B and C;
- The bottom third of the ranking is almost completely represented by developing countries with predominantly extractive type institutions (NIS of type D).

For further in-depth analysis of the specifics of individual clusters, the following data from the Global Innovation Index [Global Innovation Index, 2021] were additionally used:

Table 2
Characteristics of the NIS's basic type C «Developed and developing countries with mixed extractive-inclusive institutions with a strongly pronounced informal component (including the Post-Soviet type)»

Country	Country position in the ranking			N_i	Innovation efficiency ratio	Innovation productivity
	GII-2020 (totally 132 countries)	GCI-2019 (totally 141 countries)	HDI-2019 (totally 189 countries)			
Spain	30	**23**	**25**	**0.916**	0.663	2
Czech Republic	**24**	**32**	**27**	**0.900**	**0.823**	1
Italy	**29**	**30**	29	**0.845**	0.738	2
Slovenia	32	35	**22**	0.841	0.617	2
Cyprus	**28**	44	33	0.767	0.759	2
Portugal	31	34	38	0.753	0.673	2
Poland	40	37	35	0.686	0.607	2
Lithuania	39	39	34	0.682	0.594	3
Latvia	38	41	37	0.638	0.626	2
Hungary	34	47	40	0.630	0.701	2
Slovakia	37	42	39	0.629	0.722	2
Bulgaria	35	49	56	0.546	**0.833**	1
Greece	47	59	32	0.527	0.494	3
Russian Federation	45	43	52	0.497	0.569	2
Croatia	42	63	43	0.486	0.585	2
Romania	48	51	49	0.456	0.611	3
Montenegro	50	73	48	0.402	0.591	2
Serbia	54	72	64	0.360	0.563	2
Georgia	63	74	61	0.313	*0.443*	2
Armenia	69	69	*81*	0.289	0.707	2
Ukraine	49	85	74	0.254	**0.798**	1
Kazakhstan	*79*	55	51	0.185	*0.346*	3
Moldova	64	*86*	*90*	0.139	0.687	1
Bosnia and Herzegovina	*75*	*92*	73	*0.119*	0.447	2
Mongolia	58	*102*	*99*	*0.000*	0.626	1
Albania	*84*	81	69	*0.000*	*0.404*	2
Mean value	47	56	50	0.495	0.624	–

Notes: 1. The ranking of countries is carried out according to the indicator (N_i), the three highest values of the indicators are in bold, three lowest values are in italics.
2. Productivity of innovations: 1 – above expectations, 2 – in line with expectations, 3 – all the rest.
The source: calculated and built by the author based on [Global Competitiveness Report, 2020; Human Development Index, 2020; Global Innovation Index, 2021].

- Innovation performance at different income levels in terms of expectations of innovative development level of the country's economy and income level (Income);
- Innovation Efficiency Ratio – the ratio of the Innovation Output Sub-Index indicator to the Innovation Input Sub-Index value.

In accordance with the developed taxonomy, the national innovation system of Russia belongs to the type "Developed countries with strong informal institutions, including those of the post-Soviet type". This cluster includes other 25 different countries - both economically developed and innovative (for example, Spain, Czech Republic, Italy, etc.), as well as with an average and below average level of development, as well as with weak NIS (Albania, Mongolia, etc.). (Table 2).

Analyzing the data in Table. 2, a number of points should be noted that additionally characterize the NIS of type C:

- the basic type is characterized by relatively good productivity of innovations by the level of development (in the context of the Global Innovation Index rating data): about 2/3 of the representative countries, including the Russian Federation, have productivity at the level of "in line with expectations", five countries (Bulgaria, Moldova, Mongolia, Czech Republic and Ukraine) – "above expectations" and only four – below (see column 7 of Table 2);
- the performance of national innovation systems representing this type is lower in terms of the "innovation efficiency ratio" than in countries with NIS of type A, while half of the countries included in the cluster have a value of this indicator below the average for the cluster – 0.624 (see column 6 Table 2);
- Top 60 from Bloomberg 2021 Innovation Index [Jamrisko et al., 2021] includes 17 countries out of 26, while 6 of them (including Russia) have above-average performance;
- The leaders of the analyzed cluster of countries as a whole can be considered Spain, the Czech Republic and Italy (based on the generalization of the obtained results of the ranking, taking into account the balance of the considered parameters of innovative development).

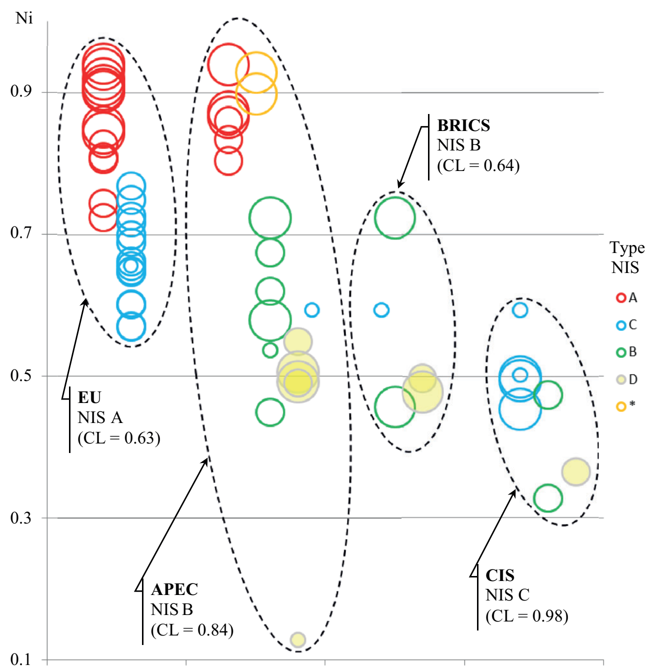
In all three ratings under consideration (GII-2020, GCI-2019, HDI-2019), in the global context, Russia is included in the first third of the lists (Table 2, columns 2-4). However, in the cluster context (among countries of the basic type C with a similar type of innovative development) demonstrates positions at the level of averages, including the generalized indicator (N_i) (Table 2, column 5). Obviously, this situation is due to the presence of obviously weaker countries in the world rankings. Among the important directions for further development in the innovation sphere, the need to adjust the ratio of "contribution/result from innovation" (Innovation Output and Innovation Input) should be noted, since the value of the indicator "innovation efficiency ratio" in Russia is below the average for the cluster (Table 2, column 6).

Thus, in order to increase the degree of validity of the results from modeling innovative development, of particular interest is not only the distribution of individual countries into leaders and outsiders in the global context, but also in each basic type of NIS. It is the understanding of the full picture of what is happening, which will allow us to assess the current real state of the NIS. At the same time, for any country, two possible approaches to innovative development in the future can be considered: either a focus on the experience of leaders of their NIS basic type (having similar development specifics), or striving for world leaders (the conditions and development nature of which differ significantly). Obviously, the second case will require much more resources (including temporary ones).

In general, the use of the described scientific and methodological approach makes it possible to solve the problems of modeling such multidimensional phenomena as the features of the functioning of individual national innovation systems, and to predict the evolution of their types. Information refined in the global and typical/cluster context may be of scientific and practical interest in identifying the characteristic features of various types of NIS, as well as substantiating strategic directions for their further development.

Separately, it should be noted that the proposed tools also make it possible to analyze existing supranational formations

Fig. 2. The neural network identification results of countries individual supranational formations



Notes: 1. Countries are ranked by integral indicator (N_i).
2. CL – the level of confidence (confidence level) of the neural network.
3. Bubble diameter – productivity of innovative development: from "below the expected level" (small diameter) to "above the expected level" (large diameter).
Source: developed by the author.

and predict the features of the new ones. For example, several supranational associations/unions were characterized during the study[1]:

- The European Union (EU) is an international formation of 28 European states that combines signs of inter- and superpower, but legally is neither one nor the other (the EU has about 500 million citizens, its share in world GDP, PPP in 2018 was about 23 %);
- Asia-Pacific Economic Cooperation (APEC) - unites 21 economies of the respective region with the aim of ensuring economic growth and strengthening the trade community, as well as facilitating investment processes (participating countries account for about 40% of the world population, share in world GDP, PPP in 2018 was about 53%);
- BRICS – includes five countries: Brazil, Russia, India, China, South Africa (share in world GDP, PPP in 2018 was about 33%).
- The Commonwealth of Independent States (CIS) is an international treaty that regulates cooperation between individual states from the former USSR (about 300 million people live in the participating countries, the share in world GDP, PPP in 2018 was about 4%).

For this purpose, based on the data sample used for clustering, averaged parameters of the functioning of these associations (according to 148 indicators) were formed, which were further identified by the neural network. Visualization of the results is shown in fig. 2.

The obtained results can be summarized as follows:

- all countries of the European Union are quite successful in their innovative development, since the integral indicator (N_i) does not fall below 0.57 (the average value is 0.75). This is the most successful result among the analyzed objects. Almost all EU countries are characterized by high productivity of innovative development - at the level of expectations and above (about 30%). According to the study, the EU largely has the characteristics of the basic type A, despite the fact that the NIS of many countries are of type C;
- APEC (includes countries with all types of NIS) is generally less successful than the European Union: the range of (N_i) is wider, from 0.13 to 0.94, with an average value of 0.67. Most of the countries have innovative development productivity at the levels “in line with expectations” and “above expectations”. With a high level of confidence, the union is recognized as the basic type B;
- BRICS - the value of the average integral indicator (N_i) for this association of countries is 0.55 (with a slight spread). Virtually all countries have innovation productivity at or above expectations. With an acceptable level of confidence, the neural network defines the object as the basic type B. Most likely, this is due to the presence of the economies of China and India, which, together with South Africa (according to the GII index), have a higher level of productivity of innovative development than expected;
- The integration of the CIS countries is less successful: the N_i indicator is at the level of 0.46, the level of innovation productivity in a third of the countries is lower than expected. The neural network recognizes it as an object with explicit features of type C.

Conclusion

The modern regionalization of political gravity centers is of a cultural and technological nature, which leads to the formation of transnational innovation ecosystems that do not necessarily occupy adjacent territories in space. Such ecosystems can cover different regions of the world, as they unite people and territories that historically have common values, sociocultural features, and technical and technological norms. For example, as a result of colonization, Australia became cultural and technological part of the Western world, although geographically it is significantly distant from Western Europe and North America. In this regard, the concept of a four-link helix of innovations, which, along with science, industry and government, also takes into account the evolutionary and socio-cultural aspects of society development, is of fundamental importance for understanding the features of national innovation system development.

The scientific and methodological approach proposed in the paper as a whole is based on the hypothesis of the expediency of regulating the development of a separate national innovation system, taking into account its belonging to a certain basic type that has specific features of development. In this regard, the paper identifies four basic types of NIS, which have characteristic features (spatial-historical, resource, etc.) that determine the capabilities and behavior of countries in relation to innovations.

The contours of a particular type of national innovation system are quite real, but they are wide and flexible (allow for intersection with others) and, thus, allow for case scenario. In this regard, the NIS vector development of a particular country are naturally diverse, but can be significantly limited by the typical specifics of functioning. This feature must be taken into account when developing individual national strategies aimed at enhancing innovation activity.

An elaborated toolkit is intended to analyze and model NIS development, taking into account typical features, its use is aimed at increasing the degree of validity of strategic decisions. With its help, it was established that the national innovation system of Russia belongs to the basic type "Developed and developing countries with mixed extractive-inclusive institutions with a strongly pronounced informal component (including the post-Soviet type)". The results of

[1] Major Alliances of the World (2020). EconomicData.ru. https://www.economicdata.ru/union.php?menu=world-unions.

its functioning (according to the analyzed statistical data) can be improved. At the same time, two approaches to adjusting innovative development are possible: either strengthening positions, focusing on the experience of countries of their own NIS type (they have similar development specifics), or following world leaders (their conditions and nature of development differ significantly). Obviously, in the second case, much more resources and efforts need mobilizing.

Four supranational associations of countries (EU, APEC, BRICS and CIS) have been identified and analyzed as a demonstration of additional possibilities of the toolkit. The relative effectiveness of the EU as a supranational formation against the background of others is noted.

The characteristic features that distinguish the author's approaches from the existing ones are the combination of genetic algorithms and cluster analysis methods to obtain a representative sample of national innovation systems, different in terms of economic development, geographical location and dominant institutions. However, their limitation is the need to involve big data for analysis, as well as blurry (moving) boundaries between different basic types of NIS, which are unstable in the long term. In this regard, further identification and distribution of specific national innovation systems between certain basic types is proposed to be carried out on the basis of neural network modeling. The resulting network model is capable of accumulating experimental knowledge, learning from it, and with high quality assigning new objects of analysis to the corresponding clusters.

The practical significance of the presented results of the study lies in the possibility of conducting variable analytical and predictive studies in the course of substantiating the optimal directions for the further development of the national innovation system in the context of global and cluster trends.

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Barriers and prospects for the use of new genetic technologies for food production: Regulatory options in the interests of the Russian economy

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Abstract

The discovery of new genetic editing technologies (new genetic technologies, NGT) made it possible to change the genetic material of organisms faster, easier, more accurate and cheaper. Gene modification in the laboratory has become the most promising method of creating new crops. In all developed countries possessing such technologies, including Russia, the question has been raised for a long time whether NGT should be qualified in the legal field in a different way than previously known traditional methods of genetic engineering, which have been in practice since the 1970s.

The Russian and European experience of evaluating technologies in the field of NGT has been studied and summarized in order to overcome the mentioned barriers in the Russian agro-industrial sphere, solve import substitution problems, ensure the sustainable development of domestic breeding and crop production, and realize the competitive advantages available today in Russian legislation for Russian innovative firms and agricultural producers.

The options of modernization of the Russian legislation are considered, which would allow to consolidate and develop the successes of domestic scientists and breeders, to make it more stable and safe to provide Russian consumers (as well as importers of Russian food abroad) with high-quality and inexpensive food products.

For the first time, a comparative analysis of studies of new genetic editing technologies in the context of their industrial implementation and legal regulation, basing on analytics from leading European centers and Russian Federation institutions, was carried out.

Keywords: technology assessment, new genetic technologies, new technologies regulations, genetically modified organism, legislative changes, foreign experience, import substitution.

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Introduction

The higher accuracy and efficiency of new genomic technologies (NGT), commonly referred to as genomic editing technologies, makes them especially promising in breeding activities. The creation of new domestic crop varieties using NGT methods can reduce dependence on seed imports, expand food production, promote export growth and attract investment in Russian companies in the agro-industrial sector and science-intensive start-ups.

At the same time, although the basic Russian law "On Genetic Engineering Activities" does not formally prohibit the circulation of plants and crops whose genome is modified by NGT methods and does not contain foreign DNA, industry legislation de facto prohibits the industrial breeding of plants and animals if they "contain genetically engineered material, the introduction of which cannot be the result of natural processes[1].

[1] Clause. 1, Art. 50 of the Federal Law from 10.01.2002 No. 7-FL "On Environmental Protection". The only exceptions are cases of growing and breeding such plants and animals during examinations, as well as research work. A similar prohibition is contained in Art. 21 of the Federal Law from December 17, 1997 No. 149-FL"On seed production".

Thus, scientific research in this area is allowed, however, the practical application of varieties obtained with the help of NGT is in the "gray zone". An entrepreneur and a scientist who have taken on the development and introduction of a new variety using advanced genetic methods together face a number of legal and organizational barriers. The main one is the task of proving that, firstly, plants (and food products based on them) obtained using genome editing are not GMOs[2], and secondly, that genetically engineered modifications are indistinguishable from those that may be the result of natural processes in nature.

Based on Russian and European experience, the presented article explores options for overcoming the mentioned barriers in order to quickly solve the problems of import substitution in seed and crop production, expand commercial food production, and create competitive advantages for Russian innovative firms and agricultural producers.

1. Description of the current situation in Russia

The discovery of NGT made it possible to change the genetic material of organisms faster, easier, and cheaper[3] [Doudna and Charpentier, 2014]. With the discovery of these "molecular scissors", gene modification in the laboratory has become the most promising method for creating new crops [Chen et al., 2019; Khalil, 2020]. In all developed countries that have such technologies, including Russia, the question has been raised for a long time whether NGT should be qualified in the legal field differently compared to the previously known traditional methods of genetic engineering that have come into practice since the 1970s[4].

In the Russian Federation, the field of genomic technologies is regulated by Federal Law No. 86-FL from July 5, 1996 “On State Regulation in the Field of Genetic Engineering Activities” (86-FL). Since 2016, a law on a virtual moratorium on the widespread use of GMOs has been in force in Russia[5] Cultivation of GM plants (except for laboratory experiments) and breeding of GM animals for food production and other business purposes is illegal.

New genomic technologies are a different tool [Trikoz et al., 2021] compared to the classical methods of genetic engineering, defined in Z86-FL as “a set of methods and technologies, including technologies for obtaining recombinant ribonucleic and deoxyribonucleic acids, for isolating genes from the body, manipulation of genes and their introduction into other organisms. Lawyers and jurists are practically unanimous in the fact that, as a result, NGT are not subject to the regulation of the specified basic law [Tarasov, 2021], that is, they can be used in economic practice.

However, the norms of sectoral legislation adopted several years ago differ in more general and strict, sometimes prohibitive language [Kudelkin, Startsun, 2019]. For example, the cultivation and breeding of plants and animals in our country, "the genetic program of which has been changed using genetic engineering methods and which contain genetically engineered material, the introduction of which cannot be the result of natural processes, is prohibited." The only exceptions are cases of cultivation and breeding of such plants and animals in the course of scientific research or examinations. These prohibitions were included in Art. 21 of the Federal Law from December 17, 1997 No. 149-FL "On seed production" in 2016. Last but not least, one of the main causes became the very resonant publications in the media and public discussions regarding genetically modified food products (up to the denial of genetic technologies in general), which could be summed up as serious public skepticism, and not only in relation to GMOs, but also to the effectiveness of the state regulation of the new technology sector as a whole.

At the same time, the regulation of breeding activities directly related to seed production is actually out of sight of Russian legislation. There is no direct regulatory relationship between genetic engineering and breeding activities, although in fact genomic technologies are a breakthrough tool in breeding work [Vetrova, 2012]. This is another barrier for effective private investment in innovative business to create new breeding achievements by genetic engineering methods, including NGT, since the differences between them are difficult to discern, especially for lawyers in the business community.

We are not talking about direct prohibitions, we are talking about a "gray zone" in legal regulation, the complexity of licensing bureaucratic procedures and, accordingly, high investment risks. Therefore, it is not necessary to count on large-scale private investments in the area under study, as well as on the transition from innovative developments using NGT to the stage of full-fledged pilot introduction of these technologies into the practice of agro-industrial enterprises. But after the pilot implementation stage, there are still many barriers to the transition to widespread implementation and scaling, which is typical for the spread of any new technologies in industry and agriculture [Kuzmin, 2021].

[2] GMOs are genetically modified (GM) organisms, including plants, whose DNA has been intentionally altered using genetic engineering methods. As a rule, these are organisms to which genes have been transferred from another organism, not necessarily related, giving them new characteristics.

[3] Basically, we are talking about technology using short palindromic repeats of DNA or CRISPR/Cas9. Opened in 2012, in 2015 the prestigious Science journal named CRISPR-Cas9 technology the breakthrough of the year. In 2020, the Nobel Prize was awarded for the research in the field of NGT.

[4] It is important that a new gene is transmitted during modification by molecular methods - insertion of a DNA fragment, without the procedure of classical selection - crossing, which also involves the transfer of new genes to new plant varieties or animal breeds, but by other, traditional methods having been used for centuries.

[5] Federal Law No. 358-FL dated July 4, 2016 “On Amendments to Certain Legislative Acts of the Russian Federation in Part of Improving State Regulation in the Field of Genetic Engineering Activities” was developed on behalf of the President of Russia V.V. Putin dated 09/01/2013.

In the absence of public investment in new domestic developments, until recently, a high share of imported seeds in the Russian market has become an economic reality, in particular for such mass and critical for food security crops as sugar beet, potatoes, vegetables, sunflower, corn. When importing them, we depend on foreign seed suppliers, often "contracted" by world leaders in the development of GM crops from the USA, Germany and Switzerland[6].

2. The role of the state in correcting the situation. Overcoming Barriers to the Economic Application of NGT

"Genomic editing, which allows you to change the genome of an organism, is a breakthrough tool that is already being applied in agriculture, industrial biotechnology, medicine and other sectors of the economy in the leading countries of the world." This is one of the key theses of the substantiation of new government approaches in the area under consideration[7].

It was the state, relying on the analysis and legal justifications of the relevant state authorities, that adopted a whole range of programs related to the development of agriculture, import substitution, scientific and technological developments, in which a prominent place is given to the use of NGT in the coming years.

As an example, we will give two subprograms of the Federal Scientific and Technical Program for the Development of Agriculture for 2017-2025 (approved by the Decree of the Government of the Russian Federation dated from August 25, 2017 No. 996) - "The development of selection and seed production of potatoes in the Russian Federation" and "The development of selection and seed production of sugar beet in the Russian federation".

The text of the last subprogram analyzes in detail the issue of critical import dependence in Russian sugar beet seed production. It is indicated that our country, ranking first in the world in terms of the area under sugar beet crops, is "significantly dependent on import supplies of seeds of sugar beet hybrids." At the same time, the volume of the market for these seeds in the Russian Federation is from 5.7 to 5.8 billion rubles.[8]

The high share of seeds of sugar beet hybrids of foreign selection in the Russian market is due to a number of reasons, including the "low level of state support for breeding and seed production of sugar beet and the lack of interest on the part of business in investing in this sector of agricultural production." The developers of the program specifically point out that when creating new domestic varieties of sugar beet, "the use of modern, but rather costly methods of molecular biology and biotechnology, has practically ceased", and new methods of "genomic selection and genome editing technology in the breeding process of sugar beet in the Russian Federation today are practically not applied. The conclusion is obvious: the competitiveness of domestically bred sugar beet hybrids is very low.

In the context of this program, it should also be noted that in terms of annual funding, specialized Russian scientific organizations are significantly (20-40 times) inferior to the research structures of foreign seed companies.

Despite increased state funding (mainly in terms of pilot projects), without an influx of corporate and private investment, the situation in this sector is unlikely to change dramatically.

3. Solving the problems to overcome barriers: taking into account foreign experience and analyzing the competitive advantages of Russian market players

Scientific research in the field of application of NGT in crop production in Russia is quite active. In accordance with WTO rules, the import of food products with GMOs is allowed. However, seeds of GM plants are not allowed to be imported. The government has the right to ban the import of GM food into Russia[9].

In all likelihood, the time has come for a substantive analysis of alternatives and making strategic decisions to justify the possibility and necessity of introducing new technologies for genome editing of plants and crops into legal and economic circulation.

The main motivation for the development of Federal Law No. 358-FL of July 4, 2016 "On Amendments to Certain Legislative Acts of the Russian Federation in Part of Improving State Regulation in the Field of Genetic Engineering Activities" (hereinafter referred to as 358-FL) was public concern about the possible harm of GMOs to humans, unpredictable impact on the environment, in particular the hypothetical threat of the transfer of new genes into the wild. What is more, even when growing already available, permitted varieties of GM corn or GM soybeans (dominant on international markets), there is an

[6] With the ban on the import of GM seeds into Russia since 2016, it is difficult to guarantee that with billions of importers, transgenic seeds do not enter domestic fields. For example, according to media reports (see, for example, Regnum on October 5, 2020), Rosselkhoznadzor confirmed the use of rapeseed seeds with an identified gene characteristic of GMOs in only one region of the Russian Federation on a total sown area of 549.76 hectares (https://regnum.ru /news/economy/3081206.html). It should be noted that seeds from foreign suppliers are usually sold on such terms that the buyer cannot leave part of the crop for planting in the next season, otherwise he violates the patent law and is subject to prosecution. The vast majority of GM seeds are developed and marketed by several multinational companies - Monsanto (USA), Syngenta (Switzerland), Dow AgroSciences (USA), Pioneer Hi-Bred (USA), Cargill (USA), Bayer CropScience and BASF (Germany) (according to the AGRO-XXI portal, https://www.agroxxi.ru/gazeta-zaschita-rastenii/zrast/rossii-nuzhny-otechestvennye-gm-kultury.html).

[7] Federal Scientific and Technical Program for the the Development of Genetic Technologies for 2019-2027 (approved by the decree of the Government of the Russian Federation dated from April 22, 2019 No. 479, developed on behalf of the President of the Russian Federation, Decree No. 680 dated from November 28, 2018 "On the Development of Genetic Technologies in the Russian Federation"). http://static.government.ru/media/files/1FErVexYSoVYFduUn1tStWlLkyrkTEmu.pdf.

[8] Id.

[9] This is the norm of Federal Law No. 358-FL of July 4, 2016: "The Government of the Russian Federation has the right to establish a ban on the import into the territory of the Russian Federation of genetically modified organisms intended for release into the environment, and (or) products obtained using such organisms or containing such organisms.

environmental threat: GM plants are resistant to herbicides, and if the cultivation technology is violated, the amount of herbicides used is often exceeded several times[10].

In Russia, as already noted, genetic editing is not within the jurisdiction of FL-358, since organisms obtained using NGT (genome editing) are not formally GMOs and are not subject to the basic Federal Law FL-86[11], which regulates exclusively transgenesis technologies (gene transfer), rather than spot editing.

Due to the absence of a law regulating breeding activities, it can be considered that the use of genomic editing methods for breeding plant varieties, animal breeds and strains of microorganisms for agricultural production purposes are legal and can be used by the breeder in his activities.

It should be noted here that genetic editing techniques can change DNA in a variety of ways: change the pointwise DNA sequence, turn genes on and off without changing the DNA code.[12], etc., however, as a rule, the final product does not contain fragments of foreign DNA (DNA another organism). This is why NGT products are currently not considered GMOs from a legal standpoint. Since foreign genetic information is not introduced, NGT can be conditionally classified as “nature-like” technologies [Kovalchuk et al., 2019; Zhironkin et al., 2019]. However, such a conclusion, made by the “method of exclusion”, by analogy with the well-known principle “everything that is not prohibited is allowed”, giving Russia a potential competitive advantage in the innovative development of oil and gas pipelines and their economic application, is insufficient. The confidence of academics, legal professionals, and even the adoption of government programs in this area is not sufficient to effectively attract business players. The question arises about the direct mentioning and clear definition of NGT in the legislation.

In the European Union, the situation is reversed: there is a Directive[13] on genetically modified organisms (hereinafter referred to as the Directive), which effectively prohibits the introduction of GM plants on the market without going through an expensive and lengthy risk assessment and monitoring procedure. In July 2018, the European Court of Justice ruled that all crops modified with NGT, including CRISPR-Cas9, are also subject to the GMO Directive. It should be noted that several years ago, after lengthy discussions, the Directive was amended, according to which individual EU Member States were given the right in their national legislation to either prohibit or allow the cultivation of GM crops, based on social, cultural and ethical prerequisites[14]. This significantly expanded the possibilities for including social and ethical factors in the discussion about possible directions for improving the legal regulation of the use of NGT.

Thus, the Russian legislation regarding the regulation of oil and gas wells is not harmonized with the international one. This, on the one hand, makes it possible to borrow experience in the development of new legal acts and procedures for licensing, monitoring and control. On the other hand, when modernizing Russian legislation, it seems expedient to follow our own path, which allows us to achieve competitive advantages for Russian agricultural producers, consolidate and develop the successes of domestic scientists and breeders, and make it more sustainable and safe to provide Russian consumers with high-quality and inexpensive food products.

To implement this approach, it is necessary at least to consider briefly possible scenarios for the legal regulation of NGT, as well as the arguments that are given in public discussions, both in Russia and abroad, on the issues related to regulatory control of biotechnology application.

4. Assessment of technologies in the field of NGT and a general review of scenarios for regulating the sphere of biotechnology according to a study by foreign technology assessment centers

In 2019, the independent Rathenau Institute (Netherlands), which specializes in technology assessment, published the report "Editing the genome of plants and crops: towards a modern biotechnology policy focused on differentiated risk assessment and broader considerations" [Habets et al., 2019] (hereinafter referred to as the report of the Rathenau Institute). The report discusses the main options for maintaining the GMO Directive in relation to NGT, as well as the possibilities for amending the Directive to exclude new genome editing methods from its scope (in cases where the final product is free of foreign DNA).

A hypothetical third option is also being considered, requiring new legislative regulation. Under this option, specific applications of NGT would have to be assessed on a case-by-case basis, based on a graded risk assessment, as well as using an assessment of the product's potential value to society and its ethical acceptability.

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[10] Kulikov K.P. (2021). GMOs are illegal in Russia. *Arguments of the week*, 23 Oct.

[11] The concept of "genetic engineering" in accordance with Federal Law-86 ("a set of methods and technologies, including technologies for obtaining recombinant ribonucleic and deoxyribonucleic acids, for isolating genes from the body, manipulating genes and introducing them into other organisms") reduces the use of molecular genetic technologies only to obtain transgenic objects, since the key to the definition of the law is "isolation of genes from the body" and "their introduction into other organisms." This takes the leading direction of genetic engineering activity - genomic editing - beyond the legal framework.

[12] Editing the genome. Overview of KWS breeding methods (2022). https://www.kws.com/.

[13] Directive 2001/18/EC of the European Parliament and of the Council from 12.03.2001, as amended, on the intentional release of modified organisms into the environment. https://pharmadvisor.ru/document/tr3602/. In order to “protect the life and health of people, the health and welfare of animals, the welfare of the environment”, the Directive introduced a licensing procedure. In particular, crops covered by the Directive require an environmental risk assessment (ERA) procedure, which implies the risk of direct, indirect and cumulative (immediate and long-term) impacts of GM crops on public health and the environment. In addition, these organisms must be monitored. In accordance with another Directive (No. 1830/2003), traceability and labeling of the relevant products is ensured in order to inform consumers.

[14] Directive 2015/412 of the European Parliament and of the Council was adopted in 2015.

The key points of the Rathenau Institute's report were then developed and supplemented by a wide range of expert judgments in the course of the foresight study carried out by the Council for Science and Technology Assessment (STOA, technology assessment body of the European Parliament), the report of which was published in December 2021 [Woensel et al., 2021] (hereinafter referred to as the STOA Report).

The method of an online survey of interested organizations and experts (stakeholders) was used in preparation of the STOA report. It included two stages and was aimed at exhaustively identifying the pro and contra arguments of the main scenarios for the legal regulation of NGT, which put forward key stakeholders from various fields of activity related to NGT[15].

It should be noted that this methodology for evaluating options and arguments can be largely (albeit with necessary adjustments) used in Russia. This would give a more reliable scientific character to the current and future discussions about the regulation of oil and gas treatment - both in society and in parliamentary and government circles, and would help to avoid excessive politicization and populism in the adoption of legislative and economic decisions.

The analysis of the mentioned reports, as well as the above considerations and conclusions regarding the Russian situation, made it possible to formulate firefly the following main options, pro and contra arguments, as well as scenarios for the legal regulation of new genome editing methods offered to Russian legislators and key economic players in order to make strategic decisions in the field of application of NGT in agricultural business. Under public support and consent solutions would provide: sustainable growth in the production and export of food products; overcoming import dependence; successful development of the innovation process based on domestic achievements in science and bioengineering.

5. Main results of the study: an exhaustive list of scenarios and the main arguments for decision making

The main options for regulating oil and gas wells in the field of their industrial application, taking into account the above considerations, include:

– *strict regulation* - bans, the use of burdensome licensing procedures for business, that is, a scenario similar to the case of GMOs;
– *deregulation* - a permissive policy in relation to NGT, subject to a number of conditions, the main of which is the absence of foreign DNA in the final product;
– *a new regulation* that will potentially combine the advantages of the first and second options and implies a balanced assessment of both each specific NGT product and each specific technology for its production in two key areas - assessment of the potential hazard of the product and assessment of the product and technology, taking into account social and ethical criteria.

When analyzing the main arguments of scientists, experts and groups of influence, possible future scenarios for the regulation of oil and gas, the following general considerations were taken into account (which must be considered a priori, bearing in mind the experience of public discussions in the Russian Federation, the need for a reliable assessment of the socio-economic prospects for the use of oil and gas to launch new domestic food products on the market):

1) significant public skepticism regarding genetically modified products (up to their demonization);
2) objectively existing uncertainties and unknown consequences of the use of NGT, not very long period of their use (about 10 years);
3) an "innate" contradiction when considering the problems of applying genetic (molecular and cellular) engineering methods between taking into account safety issues and stimulating the progress of science and innovation, between the attractiveness of a conservative, protective approach to breeding methods and the need to achieve an innovative breakthrough, competitiveness of domestic science and Russian business[16];
4) genome editing is, in a certain sense, a continuation of the methods of traditional plant breeding, which has made a significant contribution to ensuring food security in Russia;
5) Russia has excellent schools of scientists and breeders who are able to create new domestic varieties using genetic editing methods, subject to strict control conditions and “natural similarity” criteria (absence of foreign DNA, making changes that are possible in wildlife);
6) the resonance of the still not finally resolved problem of labeling products containing GMOs: in the future, NGT products need a different labeling, which, on the one hand, will ensure the freedom of choice for the consumer and the traceability of the product, and on the other hand, will remove social phobias and will contribute to the attractiveness of the product ;
7) the legislator must provide a clear and understandable policy for the public to regulate the market use of NGT products, establish transparent and effective

[15] For this survey, the results of which served as the basis for the subsequent forecasting workshop, STOA invited a core group of 25 participants from six representative groups: agribusiness and science (8 respondents); farmers and environmental NGOs (12 respondents); administrative and state bodies (2 respondents); trade and nutrition science (8 respondents); consumers and lobbying watchdogs (8 respondents); behavioral scientists (2 respondents).
[16] Using the terminology of European law, it can be said that the “precautionary principle and the principle of innovation” may conflict with each other (STOA Report).

Table 1
Strict regulation scenario

Arguments for	Arguments against
Provides a sufficiently high level of environmental protection, health, does not prohibit the use of genetic engineering methods	Правила допуска продуктов на рынок слишком строги, меры почти запретительные, процедуры очень ресурсоемкие для бизнеса
Ensures reliable, evidence-based risk assessment, follow-up monitoring, traceability, transparency when products are released to the market	Limits the state to achieve the goals of sustainable development, competitiveness of the food industry, ensuring food security in the future
Maintains freedom of choice for consumers and farmers thanks to a proven labeling system	Since there are no reliable detection methods, approved control procedures for NGT products, the development and implementation of the latter will cause difficulties and, potentially, discontent in the society.
	The risks of losing the competitiveness of national agriculture, both for Russia and Europe, are growing, since many countries (in particular, the states of South and North America, China, the countries of Southeast Asia) practice opposite approaches - in them, NGT are largely deregulated
	Risks of losing pace in science and innovation in this area, "brain drain" abroad
	GMO labeling will confuse consumers and encourage long-term rejection of NGT products

procedures for assessing risks and benefits with a clear scheme of responsibility for this assessment, based on the simple truth that after the release of new varieties into the open environment, plants can no longer be "returned back";

8) legislation regulating relations in the field of genomic research should, if possible, be proactive in nature, so as not only not to create obstacles to scientific research and innovation, but to serve as their driver, indicating key growth targets in advance and designating deliberate prohibitions and restrictions dangerous to humans and the environment.

Below is an analysis of the main arguments of experts and influence groups, based on the experience and publications of Russian experts, discussions in the legislative and public institutions of the Russian Federation, reports of the Rathenau Institute and STOA on the above scenarios.

1. Scenario of strict regulation - NGT products are equated to GMOs (Table 1). Scenario 1 for the EU implies maintaining the status quo, the GMO Directive does not change. For Russia, scenario 1 implies the introduction of tougher amendments to FL-358 and to the basic Federal Law FL-86.

2. The deregulation scenario (permissive policy for oil and gas) is shown in Table 2. Scenario 2 for the EU implies an amendment to the GMO Directive that removes NGT products from its scope. For Russia, scenario 2 implies at least the maintenance of the status quo, and at the maximum, the "legalization" of NGT in the basic law 86-FL and in industry legislation (provided that there is no foreign DNA in the final product).

3. The new legislative regulation (complex scenario, risk assessment and consideration of social and ethical aspects) is presented in Table 3. regarding social and ethical criteria.

A number of specialists from the Norwegian Advisory Council for Biotechnology (Bioteknologirådet) proposed a model that can be considered one of the options for a new comprehensive legislative regulation[17]. The Norwegian model is based on a balance of methods for assessing risk levels and socio-ethical factors. Unlike the model

[17] Bioteknologirådet (Norwegian Biotechnology Advisory Board). Genteknologiloven – Invitasjon til Offentlig Debatt (The Gene Technology Act – Invitation to Public Debate). 2017. https://www.bioteknologiradet.no/filarkiv/2017/12/Genteknologiloven-uttalelse-invitasjon-til-offentlig-debatt-web.pdf.

Table 2
Deregulation scenario

Arguments for	Arguments against
Simplifies regulation, saves material and human resources	Even small adjustments to the genome can cause big changes in the body. The absence of foreign DNA does not guarantee the safety of genetic editing
Plants produced with NGT are just as safe as those bred in the traditional way by conventional breeding methods, because they do not contain a new combination of genetic material or foreign DNA	Genomic editing technologies are new and there is little experience in safe use. Requires risk assessment and/or monitoring of newly created products
The agricultural production sector remains responsible for ensuring sustainable production and high quality food, traceability is also possible with the new labeling system	Organisms with novel traits derived from NGT can quickly enter environments where they cannot be traced, because in the event of deregulation, it is possible that developers and businesses will not be required to provide methods for detecting NGT plants
Deregulation would allow faster development and innovation, modernizing and stimulating the entire agricultural sector*	The freedom of choice of consumers should be provided with scientifically based information on food production (transparent communication between consumers, developers and manufacturers is key to supporting the development of new technologies, including NGT), the lack of complete information about NGT products is unacceptable
There are numerous examples of developments showing that NGT crops can contribute to the benefits for the agricultural sector, consumers, the environment and the economy as a whole	So far, there is no evidence that NGT will justify its promise to improve the quality and achieve sustainable food production. GMO products, even in countries where their circulation is not regulated, did not live up to the expectations of the 1980s
Stimulation of the seed sector, in which quite a lot of innovative small and medium-sized enterprises can operate	In the case of deregulation, the full-scale risk assessment envisaged for GMOs, as well as long-term monitoring of new products, is not carried out.

* Let us consider the examples of new crop species that are being successfully developed: (1) plants that are resistant to climate change and adverse environmental conditions; (2) plants resistant to new diseases and pathogens; (3) plants that can be cultivated with a sharp reduction in pesticide use; (4) "elite" and niche crops integrated into crop rotation schemes, with high yields and with a reduction in agricultural land, and others.

discussed in the Rathenau Institute report, this approach prioritizes social and ethical criteria in a complex regulatory scenario. Under this scenario, the assessment of the technology and the level of risk of NGT product is carried out mainly according to the criteria of social goals and ethical justification, and the specification of the risk category for the use of a new product occurs at the second stage (Table 4).

Conclusions

Russia will have to change the legislation on the circulation of genetically modified organisms, providing for a differentiated risk assessment depending on the technology used and social aspects, giving, in particular, real opportunities for the widespread use of new genetic technologies in food production.

It is necessary to adopt a new version of the Federal Law dated from July 5, 1996 No. 86-FL “On State Regulation in the Field of Genetic Engineering Activities”, which will clearly spell out the concept of genome editing. It is necessary to develop and adopt a federal law “On Breeding Activities”, which will contain information on selection using bioengineering, as well as the introduction of corresponding changes in the legislation on the environment, on seed production, and in by-laws of the Government of the Russian Federation.

Taking into account the current international experience in the legal regulation of oil and gas in Europe and the United States, the existing risks due to sanction pressure on Russia,

Table 3
New legislative regulation

Arguments for	Arguments against
This option is a compromise between regulation and deregulation, it can be expected to reduce the fears of citizens, preserve the principles of traceability and labeling	Risk assessment criteria (similar to GMOs) are too narrow for a correct assessment of technology, do not take into account the variety of potential consequences of the widespread use of NGT
Risk assessment according to the system of categories (risk levels) would allow for individual adjustment of the assessment procedure in each specific case, including changing, if necessary, the assigned risk category	Combining risk assessment with consideration of social/ethical criteria is not strictly scientific, it can easily become politicized and/or used for populist purposes
The structure and list of risk categories, in accordance with the existing proposals of experts from a number of countries, may be similar to the well-established system of risk categories in the creation of GMOs*	Deregulation of the use of "small" changes in the plant genome (notifying the introduction to the market) will mean that for many crops obtained by NGT methods, risks to humans and the environment will not be assessed
Connecting ethical criteria and predicting social consequences to risk assessment would facilitate the entry into the market of innovations that are beneficial not only from the point of view of business, but also well-being of citizens and the environment	This scenario does not take into account the unintended consequences of genetic editing (CRISPR and similar are still relatively new methods), while it is known that even small changes in the genome can have critical consequences for the whole organism.
Genetic editing introduces only very small changes in DNA that are indistinguishable from the results of conventional plant breeding methods.	At present, it is not possible to convincingly prove that the "small" genetic changes introduced with NGT are completely analogous to those that can be achieved using traditional methods of mutagenesis and selection; it is extremely difficult to make a comparison between them (there are no developed criteria). Thus, it is impossible to reliably verify the "natural similarity" of one or another NGT.
This scenario will facilitate wider adoption of advanced technology assessment methods	Questions that are very complex and unresolved even in the theory: who will be authorized to set the criteria? Who will conduct the proposed risk assessment?

* This takes into account factors such as the method of genetic modification, the type of change made to the sequence, the stability of the changes made, the risks of the modified organism spreading in the environment, and others

Table 4
New legislative regulation with priority of social assessments

Arguments for	Arguments against
Potentially solves social problems (sustainability, ethical justification and economic benefit). This procedure could be considered as obtaining a "social license".	The terms and criteria of social value and ethical acceptability are difficult to unambiguously define, which entails vulnerability to speculation (promises of "pennies from heaven" when introducing a new NGT culture from applicants) in the hope to reduce the requirements for risk assessment in relation to NGT methods
Provides benefits for consumers and enterprises in the production chain, puts environmental protection at the forefront	The scenario requires large public resources, and it is not clear who will bear the brunt of the costs connected with assessing the socio-economic impacts of the new technology. Compliance with social values can be interpreted in a variety of ways and it requires separate consideration, especially taking into account ongoing rapid geopolitical changes.
This incremental approach may be more effective; it would save business resources that are required for risk assessment in the second stage, although at the risk of weeding out promising innovations based on high-quality social and ethical criteria	The scenario does not explain how the risks and potential rewards will be balanced: is it acceptable to admit more risks if the potential product should bring more benefits to society? Who decides which social values are more important than the risks to the safety of the use of certain NGT crops?
The scenario provides more opportunities for the authorities to maintain control over the compliance of the sphere of technology and innovation with the goals of the state policy pursued	Many experts believe that the assessment of product safety should be carried out aside from the assessment of the social value of the product rather than in connection with it.

China's plans for a well-known liberalization of legislation on GMOs[18] Russia needs new domestic crops obtained by the "molecular scissors" methods. Currently, the legislation of the Russian Federation is prohibitive in relation to GMOs and implicitly liberal in relation to products of new genomic technologies. This situation creates a number of competitive advantages that must be preserved and strengthened, implying the need to improve the regulatory framework for genetic engineering activities.

The main scenarios for oil and gas pipeline regulation, pro and contra arguments, comparison of Russian and foreign approaches can be applied in making strategic decisions by both regulatory authorities and economic players. In general, the initial situation is in favor of the fact that the Russian innovation sphere and the food production industry can realize their existing competitive advantages in the coming years.

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[18] In July 2021, the General Reform Commission of the Central Committee of the Communist Party of China approved the "Action Plan for the Revival of the Seed Industry". The document attaches great importance to molecular methods of biological research, including the development of new genetically modified organisms (according to "AgroXXI-agroindustrial portal", 02/17/2022).

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Approaches to managing innovative risks of industrial companies

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Abstract

The article reviewed the literature, which made it possible to identify groups of industrial companies in terms of sustainability and sensitivity to innovation risks. The conducted cluster analysis made it possible to single out four groups of Russian industrial companies according to the level of stability and sensitivity to innovation risks: leaders, innovators, conservatives and low-performing companies.

A study was also conducted to identify the level of risk appetite and the level of risk management culture for each cluster of industrial companies in terms of sustainability and sensitivity to innovative risks. As part of the study, approaches to risk management were identified for each cluster of industrial companies in terms of the level of sustainability and sensitivity to innovative risks. The article proposes measures to improve the risk management system of industrial companies. These activities will ensure the continuous development of industrial companies and increase their level of competitiveness.

Keywords: innovation risk, risk management, clusters of industrial companies, risk appetite level, types of innovation activity, risk management system.

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Introduction

In the context of widespread robotization and digitalization, the influence of innovative risks on the development of industrial companies and their competitiveness is increasing. This is due to the processes of globalization, transformation and the emergence of new markets, changes in the level of demand, and the complication of technologies. Under the current conditions, it is important to ensure the ability of companies to withstand emerging threats and risks, which depends on many factors, including the level of risk management culture in the company, the risk management approach in it, as well as the level of risk appetite. Risk management is a reliable tool in the management of innovative risks due to modern conditions.

1. The level of resilience and risk sensitivity of industrial companies

The ability of Russian industrial companies to manage innovation risks depends on the level of sustainability and sensitivity to them. To ensure the competitiveness of industrial companies, the consulting company PWC proposed to follow two strategies at the same time: the creation of flexible and sensitive risk management systems that allow you to quickly adapt to emerging innovative risks; ensuring the stability of companies, which will minimize emerging risks. Ensuring sensitivity to risks will allow to use the capabilities of industrial companies for their long-term development, resistance to risks will help them to achieve their goals [A path to the goal .., 2016].

Based on a review of Russian and foreign literature, a matrix of sustainability and sensitivity to innovation risks was developed (Table 1). The matrix of stability and sensitivity to risks was taken as a basis, proposed by the consulting company PWC [Path to the goal.., 2016], which conducted a study in terms of the stability and sensitivity of companies to all types of risks. The author of this paper explores sustainability and sensitivity to innovation risks. Within the framework of this study, a matrix of the level of stability and sensitivity to innovation risks was constructed in terms of two parameters: the level of stability and the level of sensitivity to innovation risks. Risk resilience implies a company's ability to manage innovation risks through well-established business processes within the company, a strong corporate culture, and advanced risk management. Risk sensitivity implies the ability to adapt to emerging risks and the company's ability to be flexible [Way to the goal.., 2016; Bai et al., 2020; Avagyan et al., 2021]. In this regard, industrial companies can be divided into four groups according to the level of stability and sensitivity to innovation risks: leaders, innovators, conservatives, and low-performing companies.

Let us consider each group of industrial companies in terms of the level of sustainability and sensitivity to innovation risks in more detail.

Leaders include industrial companies that have a high level of risk tolerance and a high level of risk sensitivity. This means that leading companies are able to reflect the threats and innovative risks of the external environment due to the availability of the necessary resources, as well as quickly adapt to emerging innovative risks [A path to the goal.., 2016; Bai et al., 2020; Avagyan et al., 2021].

Innovators are companies that have a high level of sensitivity to innovation risks, but a low level of resistance to them. Innovative companies may not have a sufficient level of internal strength to manage risks, but they are flexible and can quickly adapt to emerging environmental conditions [A path to the goal.., 2016; Bai et al., 2020; Avagyan et al, 2021].

Conservatives include companies that have low sensitivity to innovation risks, but these companies are resistant to innovation risks. In this regard, industrial companies belonging to the category of "Conservatives" can manage innovation risks due to strong risk management and developed corporate culture [A path to the goal.., 2016; Bai et al., 2020; Avagyan et al., 2021].

Low-performing industrial companies include those organizations that have a low level of resistance to innovation risks and a low level of sensitivity to innovation risks. These companies cannot effectively manage innovation risks either from the standpoint of flexibility or from the standpoint of having internal resources [A path to the goal.., 2016; Bai et al., 2020; Avagyan et al., 2021].

2. Methodology for assessing industrial companies in terms of sustainability and sensitivity to innovation risks

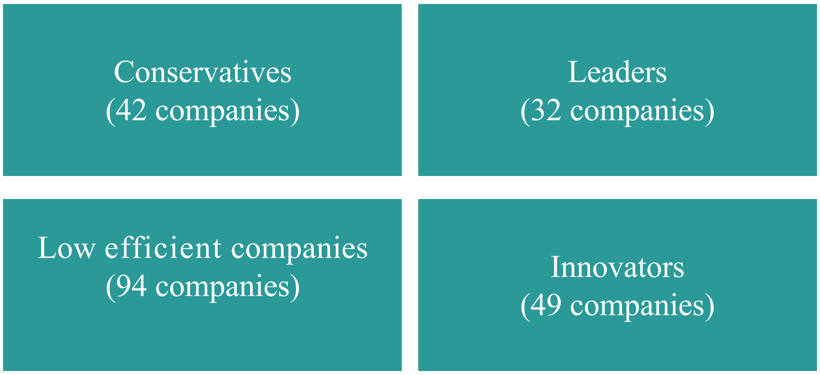
The proposed resilience and risk sensitivity matrix has been tested. A cluster analysis was carried out, which made it possible to identify homogeneous groups of industrial companies in terms of sustainability and sensitivity to innovation risks, which helped to identify barriers and bottlenecks in the

Table 1
The matrix of sustainability and sensitivity to innovation risks

	Low sensitivity to innovation risks	**High sensitivity to innovation risks**
High resistance to innovation risks	Conservatives	Liders
Low resistance to innovation risks	Low effective companies	Novators

Source: compiled by the author according to [A path to the goal.., 2016; Bai et al., 2020; Avagyan et al., 2021].

Fig. 1. Clusters of industrial companies by the level of sustainability and sensitivity to innovation risks



Source: compiled by the author.

implementation of a risk management system for industrial companies.

The study was carried out in two stages. At the first stage, a survey of Russian industrial companies was conducted in order to identify their level of sustainability and sensitivity to innovation risks. 200 questionnaires were sent out, with a response rate of 59% (117 industrial companies). At the second stage, a cluster analysis was carried out based on the results of the survey. Clustering of industrial companies was carried out using the Statistica software package.

The cluster analysis was carried out in three stages [Birch, 2015; Sharpe, 2018; Example of use.., 2020; Hallikas et al., 2020; Fraser et al., 2021].

1. 1. Ten factors (variables) were selected for cluster analysis. Each variable reflects one of the evaluation parameters: the level of resistance to innovation risks or the level of sensitivity to innovation risks. Variables that were selected to reflect the parameter of the level of sensitivity to innovation risks: recognition of innovative opportunities for the company before competitors; applying business intelligence to recognize innovative opportunities; rapid realization of the company's growth opportunities through innovation; adaptation of the organizational structure for the implementation of innovative opportunities; timely adaptation to innovative changes in business. The variables that were selected to reflect the level of risk tolerance parameter are: mobilization of the company's internal resources to take effective measures in the field of innovation; prompt implementation of plans to ensure the continuity of the company's innovative activities after emerging threats; prompt instruction of the company's stakeholders about the measures taken in the field of innovation; timely attraction of external resources in the event of risks associated with innovation; timely financing of continuity risks of innovation activity [A path to the goal.., 2016; Bai et al., 2020; Avagyan et al., 2021].

2. As part of the second stage, standardization (normalization) of indicators was carried out in order to be able to compare the composition of the compared groups according to the formula (1) [Example of use .., 2020]:

$$x_{si} = \frac{x_i - \bar{x}_i}{\sigma_i^2}, \quad (1)$$

where x_{si} – is the standardized value of the i factor, x_i is the actual value of the i factor, $\bar{x}_i$ is the average value of the i factor, σ_i^2 is the standard deviation of the i factor.

3. At the third stage, cluster analysis was carried out using the *k*-means method.

3. The results of cluster analysis of industrial companies in terms of sustainability and sensitivity to innovation risks

Based on the cluster analysis of industrial companies in terms of sustainability and sensitivity to innovation risks, four groups of companies were identified. The results of cluster analysis are shown in Fig.1.

Thus, four clusters of industrial companies were identified according to the level of sustainability and sensitivity to innovation risks.

The Leaders cluster includes industrial companies that have a high level of resistance to innovation risks. They are characterized by the mobilization of internal resources of the company to take effective measures in the field of innovation; prompt implementation of plans to ensure the continuity of the company's innovative activities after emerging threats; prompt informing the company's stakeholders about the measures taken in the field of innovation; timely attraction of external resources in the event of risks associated with innovation; timely financing of the risks related to continuity of innovation activity. Also, these companies have a high level of sensitivity to innovation risks: recognition of innovative opportunities for the company ahead of competitors; applying business intelligence to recognize innovative opportunities; rapid realization of the company's growth opportunities through innovation; adaptation of the organizational structure for the implementation of innovative opportunities; timely adaptation to innovative changes in business [A path to the goal.., 2016; Bai et al., 2020; Avagyan et al., 2021].

The "Innovators" cluster includes industrial companies that have a high level of sensitivity to innovation risks: recognition of innovative opportunities for the company ahead of competitors; applying business intelligence to recognize innovative opportunities; rapid realization of the company's growth opportunities through innovation; adaptation of the organizational structure for the implementation of innovative opportunities; timely adaptation to innovative changes in business. However, such industrial companies have a low level of resistance to innovation risks: mobilization of the company's internal resources to take effective measures in the field of innovation; prompt implementation of plans to ensure the continuity of the

Table 2
Results of the analysis of variance

Variables	Dispersion analysis					
	Dispersion between clusters	Number of freedoms for interclass variance	Intragroup dispersion	Number of liberties for intragroup dispersion	The value of the F-criterion for testing the hypothesis of inequality of variances between clusters within them	Significance levels (p)
Recognizing innovative opportunities for the company ahead of competitors	18.88520	3	0.114796	16	877.394	0.000000
Using Business Intelligence to Recognize Innovation Opportunities	18.93366	3	0.066341	16	1522.119	0.000000
Rapid realizing of company growth opportunities through innovation	18.88555	3	0.114452	16	880.042	0.000000
Adaptation of the organizational structure to realize innovative opportunities	18.93466	3	0.065336	16	1545.618	0.000000
Timely adaptation to innovative business changes	18.91766	3	0.082338	16	1225.361	0.000000
Mobilization of the internal resources of the company to take effective measures in the field of innovation	13.19407	3	5.805927	16	12.120	0.000217
Prompt implementation of plans to ensure the continuity of the company's innovative activities after emerging threats	12.99625	3	6.003754	16	11.545	0.000281
Prompt informing of the company's stakeholders about the measures taken in the field of innovation	13.40904	3	5.590959	16	12.791	0.000161
Timely attraction of external resources in the event of risks associated with innovation	13.37311	3	5.626885	16	12.675	0.000170
Timely financing of innovation continuity risks	13.05655	3	5.943445	16	11.716	0.000260

Source: compiled by the author.

company's innovative activities after emerging threats; prompt informing the company's stakeholders about the measures taken in the field of innovation; timely attraction of external resources in the event of risks associated with innovation; timely financing of the risks related to continuity of innovation activity [A path to the goal.., 2016; Bai et al., 2020; Avagyan et al., 2021].

The cluster "Conservatives" includes industrial companies that have a low level of sensitivity to innovation risks: recognition of innovative opportunities for the company ahead of competitors; applying business intelligence to recognize innovative opportunities; rapid realization of the company's growth opportunities through innovation; adaptation of the organizational structure in order to implement innovative opportunities; timely adaptation to innovative changes in business. At the same time, these industrial companies have a high level of resistance to innovation risks: mobilization of the company's internal resources to take effective measures in the field of innovation; prompt implementation of plans to ensure the continuity related to the company's innovative activities after emerging threats; promptly informing the company's stakeholders about the measures taken in the field of innovation; timely attraction of external resources in the event of risks associated with innovation; timely financing of the risks of continuity of innovation activity [A path to the goal.., 2016; Bai et al., 2020; Avagyan et al., 2021].

The "Low-performing companies" cluster includes industrial organizations that have a low level of resistance to innovation risks: mobilization of the company's internal resources to take effective measures in the field of innovation; prompt implementation of plans to ensure the continuity of the company's innovative activities after emerging threats; prompt informing the company's stakeholders about the measures taken in the field of innovation; timely attraction of external resources in the event of risks associated with innovation; timely financing of the risks related to the continuity of innovation activity. At the same time, industrial companies of this cluster have a low level of risk sensitivity parameters: recognition of innovative opportunities for the company ahead of competitors; applying business intelligence to recognize innovative opportunities; rapid realization of the company's growth opportunities through innovation; adaptation of the organizational structure in order to implement innovative opportunities; timely adaptation to innovative changes in business [A path to the goal.., 2016; Bai et al., 2020; Avagyan et al., 2021].

The cluster of industrial companies that belong to the group of low-performing companies turned out to be the most numerous (94 companies), which indicates a low level of innovation risk management culture, the inability to effectively implement a comprehensive risk management system. Such companies cannot develop effectively and have a low level of competitiveness.

To confirm the accuracy and efficiency of cluster analysis, an analysis of variance was carried out [Birch, 2015; Sharpe, 2018; Example of use.., 2020; Hallikas et al., 2020; Fraser et al., 2021], the results of which are presented in Table. 2. They confirm the high efficiency of the performed cluster analysis.

The reliability and effectiveness of the cluster analysis performed was confirmed by the following criteria [Birch, 2015; Sharpe, 2018; Example of use.., 2020; Hallikas et al., 2020; Fraser et al., 2021]:

1. Inequality of F-criterion values. The hypothesis about the inequality of variances between clusters is confirmed. At the same time, the hypothesis about the inequality of dispersions within clusters was proved.

2. Values of significance levels ($p < 0{,}05$) cindicate a low level of unreliability of the obtained research results in cluster

Table 3
The level of risk appetite of industrial companies of various clusters in terms of sustainability and sensitivity to innovation risks

Company clusters	Low level of risk appetite		Middle level of risk appetite		High level of risk appetite	
	Number of companies	Share of companies in the cluster (%)	Number of companies	Share of companies in the cluster (%)	Number of companies	Share of companies in the cluster (%)
Leaders	1	3	6	19	25	78
Innovators	8	17	31	63	10	20
Conservatives	6	14	28	67	8	19
Low effective companies	70	74	14	15	10	11

Source: compiled by the author according to [Birch, 2015; Risk Management.., 2018; Zhou et al., 2021].

Table 4
Risks affecting the innovative activity of industrial companies

Innovative activities	Leaders	Innovators	Conservatives	Low-efficiency companies
Implementation of new technologies in production processes in order to improve existing products	Market risks	Innovation risks	Operational risks	Innovation risks, market risks, operational risks
Introduction of new technologies into production processes in order to develop new products	Market risks	Innovation risks	Market risks	Innovation risks, market risks, operational risks
Implementation of marketing innovations	Market risks	Market risks	Market risks	Market risks
Innovations in IT sphere	Innovation risks	Innovation risks	Innovation risks	Инновационные риски
Changes in the personnel model of the company	Operational risks	Operational risks	Operational risks	Operational risks
Changes in the company's business model	Innovation risks, market risks, operational risks	Innovation risks, market risks, operational risks	Innovation risks, market risks, operational risks	Innovation risks, market risks, operational risks

Source: compiled by the author according to [Risk management.., 2018; Wang, Bi, 2020; Haar and Gregoriou 2021].

analysis. Therefore, the allocation of four homogeneous groups of industrial companies in terms of sustainability and sensitivity to innovation risks is justified. Therefore, the results of the conducted cluster analysis are reliable and effective.

4. Research of risk management systems of industrial companies of various clusters in terms of sustainability and sensitivity to innovation risks

Within the framework of this article, a study was conducted to analyze risk management culture of each cluster of industrial companies regarding the level of sustainability and sensitivity to innovative risks.

Table 3 presents the results of a survey of 117 industrial companies that were asked to evaluate their risk appetite, that is, the maximum possible level of risk that an industrial company is ready to take [Birch, 2015; Risk Management.., 2018; Zhou et al., 2021].

Leading companies have a high level of risk appetite - this was noted by 78% of respondents. Only 19% of the leading companies said that they adhere to the average level of risk appetite in their activities. This is due to the fact that such industrial companies are quite flexible, that is, they can quickly adapt to the conditions of the external environment. At the same time, leading industrial companies have a sufficient reserve of resources, which makes it possible to ensure their sustainability.

Companies-innovators (63% of respondents) and conservatives (67% of respondents) are characterized by an average level of risk appetite. This means that such industrial companies pursue a moderate risky policy, but they are characterized by low resistance to innovation risks, as for innovators, or low sensitivity to innovation risks as for conservatives. In this regard, industrial companies cannot fully take high-risk decisions, as this can have detrimental consequences for them.

Low-performing industrial companies noted that they have a low level of risk appetite and are not ready to make high-risk decisions. This position is shared by 74% of the respondents. Only 11% of respondents noted that they are characterized by a high level of risk appetite, and 15% of respondents identified the average level of the company's risk appetite.

It should be noted that, according to the results of the study, the higher the level of stability and sensitivity to innovative risks of industrial companies, the higher the level of their risk appetite and the more risky decisions they are ready to take.

Within the framework of this article, a study was also conducted in terms of the risks affecting the innovative activities of industrial companies of various clusters regarding the level of sustainability and sensitivity to innovative risks [Risk management.., 2018; Wang, Bi, 2020; Haar and Gregoriou 2021]. The results of a survey of 117 industrial companies are presented in Table 4.

Thus, low-performing companies are exposed to a high level of various risks. Respondents noted innovative, operational and market risks that affect various types of innovative activities of industrial companies.

For innovators and conservatives, the level of risks that pose a threat to their innovation activities is lower, but the impact of innovation risks is quite high.

According to the results of the survey, it was revealed that market risks are the most significant for leading companies and they should be treated with special attention.

The article also conducted a study of what programs and tools (technologies) are used by industrial companies of various clusters towards the level of sustainability and sensitivity to innovative risks in risk management [Risk Management.., 2018; Fujii, 2021; Jia et al., 2021]. The survey results are presented in Table. 5.

Leading companies are actively using digital technologies such as big data, cloud technologies and blockchain in their risk management activities. Also, at a fairly high level, artificial intelligence and virtual reality technologies are used.

Industrial innovators and conservatives are quite active in risk management when they use big data and cloud technologies, but to a lesser extent they use blockchain technologies, artificial intelligence and virtual reality.

Low-performing companies use only cloud technologies and big data in their risk management activities to a small extent.

As part of this study, a survey of industrial companies was conducted in terms of identifying the risk management approach that companies adhere to. The research results are presented in Fig. 2.

Thus, based on a survey of industrial companies of various clusters in terms of sustainability and sensitivity to innovation risks, it was revealed that low-performance companies are characterized only by taking into account some risks, and their management is adaptive in order to eliminate the consequences of emerging risks. Conservative companies adhere to the traditional concept of risk management. This means that only certain risks are managed in an industrial company, and some preventive measures are being developed to manage them. Innovative companies adhere to the corporate risk management system. This means that risk management is integrated into the company's core business processes. At the same time, absolutely all employees of an industrial company are involved in risk management processes; risk management in this case acts as a tool for business planning; risk management is carried out on a top-down basis. Leading companies adhere to risk-based business conduct in risk management; risk management is carried out on a bottom-up basis. Risk management processes are integrated into all vertical and horizontal levels an industrial company management; special methods of risk assessment and management are also applied [Management of operational risks.., 2018; Kamiya et al., 2020; Yingfan et al., 2020; Elahi, 2022].

Table 5
The use of digital technologies related to robotics
in the management of innovative risks of industrial companies

Digital instruments (programmes)	Share of surveyed companies in the cluster (%)
Leaders	
Artificial intelligence	63
Cloud technologies	88
Big data	91
Blockchain	64
Virtual reality	61
Innovators	
Artificial intelligence	53
Cloud technologies	62
Big data	64
Blockchain	49
Virtual reality	43
Conservatives	
Artificial intelligence	57
Cloud technologies	61
Big data	65
Blockchain	43
Virtual reality	44
Low-efficiency companies	
Artificial intelligence	0
Cloud technologies	17
Big data	3
Blockchain	0
Virtual reality	0

Source: compiled by the author according to [Risk management.., 2018; Fujii, 2021; Jia et al., 2021].

Fig. 2. Approaches to risk management of industrial companies, taking into account their level of resilience and sensitivity to innovative risks

Leaders	**Risk-Based Business Conduct:** • bottom-up risk management; • risks are taken into account in all business processes of the company; • risk management in all functional divisions of the company; • specialized risk management methods
Innovators	**Corporate risk management system:** • top-down risk management; • integration of risk management into the main business processes of the company; • participation of all employees of the company in risk management
Conservatives	**The traditional concept of risk management:** • managing only the key risks of the company; • development of preventive risk management measures
Low-efficiency companies	**Risk accounting:** • adaptive principles of risk management

Source: compiled by the author according to [Operational Risk Management.., 2018; Kamiya et al., 2020; Yingfan et al., 2020; Elahi, 2022].

Thus, leading companies are characterized by the highest level of risk management. It is important for industrial companies of all clusters to achieve a risk-based business approach in their activities, which will ensure the continuous development of an industrial company and a high level of competitiveness.

5. Recommendations for risk management

To ensure effective management of innovation risks in all clusters of industrial companies in terms of sensitivity and resistance to innovation risks, it is necessary to provide a model of three lines of defense, which involves three levels of risk management [Management of operational risks.., 2018; Sakai, 2018; Niu et al., 2021]:

First line of defense. At this level, risk management should be carried out by heads of business functions in companies whose competencies include:

- Management of risks;
- introduction of risk management into the company's business processes;
- identification and assessment of risks.

Second line of defense. Risk management at this level should be carried out by the risk management service, whose functions are:

- description of risk management processes;
- taking into account risks when building the company's strategy;
- management, coordination and control of risks at all levels of management in an industrial company;
- building links between the first and third lines of defense;
- control over individual risk groups.

Third line of defense. At this level of risk management, an internal audit of an industrial company is carried out:

- providing communication with the company's management when it comes to risk management monitoring;
- ensuring systematization in risk assessment and reporting;
- providing control over the second line of defense in terms of the risk management process.

Building a model of three-line defense in innovation risk management will allow to create a comprehensive risk management system that will cover all vertical and horizontal levels of company management.

At the same time, to ensure comprehensive systemic risk management in industrial companies, it is necessary to adhere to the principles of Risk Intelligent [Risk under control.., 2017; Niu et al., 2021]:

1. Ensuring a unified understanding and approach to risk management in all departments of the company and at all levels of management, which will ensure a unified vision of the company in this matter and eliminate contradictions as much as possible in the risk management process.

2. It is important to adhere to a single risk management model for an industrial company within a certain risk management standard (COSO, CoCo, FERMA, CAS, AS/NZS, etc.). The chosen risk management model will allow building a comprehensive risk management system in an industrial company, adapting it to the specifics of the company.

3. Ensuring those responsible for managing each risk in the company in all departments and at all levels of company management. This will ensure transparency and clarity in risk management, since each division is responsible for certain groups of risks.

4. The adoption of risk management policy is one of the functions of the company's management. It is responsible for the adopted risk management policy, as well as for the risk management program implemented in the industrial company.

5. It is important to ensure continuous monitoring and control of the functioning risk management system, which will correct bottlenecks and ensure continuous risk management.

Thus, providing a model of three lines of defense in risk management of industrial companies, taking into account the principles of Risk Intelligent, will allow the company to increase the level of resistance to all risks and the level of sensitivity to them, which will make the company more competitive.

6. Conclusions and results

The article presents the results of a cluster analysis of industrial organizations in terms of sustainability and sensitivity to innovation risks. Four groups of industrial companies have been identified according to the level of stability and sensitivity to innovation risks: leaders, innovators, conservatives and low-performing companies. The division of companies into four clusters made it possible to identify problems and bottlenecks in the management of innovative risks of industrial companies.

The article also conducted a study of risk management culture and the level of risk appetite. For each cluster of industrial companies, the level of risk appetite that the company is ready to take is determined. The study made it possible to determine the risks that affect various types of innovative activities of industrial companies of various clusters in terms of the level of sustainability and sensitivity to innovative risks. The approach to risk management of industrial companies, significant for each cluster, is also defined.

It should be noted that in order to ensure the development and competitiveness of industrial companies in various clusters in terms of sustainability and sensitivity to innovative risks, it is necessary to build a model of three-line defense in risk management, as well as adhere to the principles of Risk Intelligent. These measures will ensure a comprehensive risk management system.

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