

Modeling the Activity of Small and Medium Enterprises using Set Theory



I. S. Pinkovetskaia, I. N. Nikitina, T. V. Gromova

Abstract: *One of the directions of the Strategy for the Development of the Information Society in the Russian Federation for 2017-2030 is elaboration of technology for processing data on the activities of economic entities, as a tool for analyzing economic activity and making decisions based on the most complete amounts of information. The number of small and medium enterprises in certain industries and regions of Russia amounts to tens and hundreds of thousands. The assessment of their performance indicators requires improving methods for the formation and analysis of relevant databases, as well as the development of computer economic and mathematical models. Taking into account the large number of enterprises included in the relevant aggregates, the authors propose a new original approach to the description of their performance indicators. The study aims to develop a methodology for a system analysis of performance indicators of small and medium enterprises using set theory. These indicators are formed on the basis of a combination of different variants of their sets. The authors also consider the interrelations between the indicators characterizing the sets of small and medium enterprises belonging to different size categories, industries and territories. The results of the study can be used to develop technology for processing data on the activities of business entities, as a tool for analyzing economic activity and making decisions. They make it possible to establish patterns and trends in the development of various aggregates of SMEs, substantiate proposals and recommendations for improving their functioning on the basis of the characteristics specific to particular aggregates, and provide a differentiated approach to solving problems of state regulation of entrepreneurship.*

Keywords: *small enterprises, medium enterprises, performance indicators, types of economic activity, set theory.*

I. INTRODUCTION

The Strategy for the development of the information society in the Russian Federation for 2017-2030 pays great attention to the problems of digital economy, namely, the processing of large amounts of information and the using the

results of its analysis [1]. The relevant measures should allow increasing the efficiency of various types of production activities and improving technologies. The number of small and medium businesses in certain industries and regions of Russia amounts to tens, and in some cases hundreds of thousands [2]. Therefore, the study of patterns that characterize the indicators of their activity requires improving the methods of formation and analysis of relevant databases, as well as the development of computer economic and mathematical models. This work should be based on new methodological approaches, including the application of a more advanced mathematical apparatus, such as set theory.

In recent years, the importance of small and medium enterprises has increased significantly. Modern small and medium business is one of the largest sectors of both national and regional economies of Russia [3, 4]. Entrepreneurship is a complex system that includes a large number of independent business entities. Each of them determines its own goals and objectives based on the specific situation, and is an active participant in socio-economic processes. The development of entrepreneurship and improvement of its efficiency requires the analysis of the performance level reached by business structures [5, 6]. This analysis should be based on reliable and complete information on the activities of economic entities. Therefore, the following problems are relevant at present: assessing the state of the national and regional sectors of small and medium enterprises, establishing patterns and trends in the development of modern entrepreneurship, institutional support, substantiating ways to increase the efficiency of its regulation and improving the forms, methods and tools of the state support for entrepreneurial structures.

The Federal Law "On the Development of Small and Medium-Sized Enterprises in the Russian Federation" [7] defines the criteria for classifying business entities as entrepreneurial structures. The main criterion is the number of employees, which for a small enterprise should not exceed 100 people, and for a medium enterprise is in the range from 101 to 250 people. Small and medium business also includes individual entrepreneurs, i.e. individuals who conduct business activities. Thus, when considering entrepreneurship in our country, it is necessary to note that the entrepreneurial structures, hereinafter referred to as SMEs, include small enterprises, medium enterprises and individual entrepreneurs.

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* Correspondence Author

I. S. Pinkovetskaia*, Institute of Economics and Business, Ulyanovsk State University, Ulyanovsk, Russia. Email: pinkovetskaia@gmail.com, judy54@yandex.ru

I. N. Nikitina, Institute of Management, Samara State University of Economics, Samara, Russia

T. V. Gromova, Institute of Management, Samara State University of Economics, Samara, Russia

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II. LITERATURE REVIEW

Information technology and the digital economy provide new opportunities to study the patterns of economic development [8]. In our opinion, it seems appropriate to use the mathematical apparatus of the set theory to describe the performance indicators on the sets of SMEs. Much attention has been paid to the development of set theory in the works of many scientists, among which are [9, 10].

In the monograph [10] it was pointed out that the researches have to deal with that difficult to define concept, which is expressed by the word “aggregate”. For example, one can talk about the aggregate of people currently present in this room, about the aggregate of geese swimming in the pond, ostriches living in the Sahara, etc. In each of these cases it would be possible to use the word “set” instead of the word “aggregate”. Set theory, which studies elements of arbitrary nature, has received significant development up to know [11, 12].

Taking into account the foregoing, the article presents some results of the authors' research related to the development of a methodology for system analysis of SMEs performance indicators using set theory.

III. METHODOLOGY

The number of small and medium enterprises in Russia in 2018 amounted to more than 5 million [2]. Description of indicators for each individual enterprise (entrepreneur) with their subsequent aggregation is a very complex and time-consuming process. Therefore, it seems logical to analyze performance of the aggregate of entrepreneurial structures based on the consideration of overall performance of the aggregate as a whole. Aggregates of SMEs can be formed on the basis of different approaches. It is essential that entrepreneurial structures included in the aggregate have something in common, that is, correspond to one or several specific features. Considering the experience accumulated to date, the authors propose to consider three important characteristics when forming aggregates of SMEs: size-organizational, sectoral and territorial.

Aggregates of small, medium enterprises and individual entrepreneurs can be formed on the size and organizational basis. It is significant that individual entrepreneurs differ from enterprises not only in their organizational form, but in the absolute majority of cases, the number of employees which is significantly lower than even in small enterprises.

Most products manufactured by business entities are sold in intra-regional markets. The niche occupied by entrepreneurial structures in all regions of the country is quite homogeneous. Enterprises and entrepreneurs provide their products to both the population and other enterprises and organizations. The main feature of entrepreneurial structures is their proximity to consumers of goods and services, as well as labor structures.

The need to consider the aggregate of entrepreneurial structures operating in the regions of Russia (republics, territories, regions and cities of federal significance) is due to a significant differentiation of the values of indicators characterizing the activities of SMEs in these territorial units. The formation of entrepreneurship was uneven, which was

due to repeated changes in the legislative and regulatory base, as well as the peculiarities of regional development. The level of development of entrepreneurial structures in specific territories was determined by a large number of both objective and subjective factors. On a territorial basis, the aggregate of SMEs can be formed in the country as a whole, its regions, as well as in municipalities.

One of the sections of this general set theory, devoted to operations on abstract sets, presented in particular in the articles [13, 14, 15], can be used to describe the performance indicators of aggregates of SMEs.

Each entrepreneurial structure included in the aggregate is characterized by a certain set of indicators $(P_1, P_2, \dots, P_x, \dots, P_t)$, where t – the total number of indicators characterizing the activities of the business structure in question. The aggregate of SMEs can be put in line with as many sets as the number of performance indicators considered in the process of research. Accordingly, the indicator P_x is an element of the set A_x , that is

$$p_1 \in A_1, p_2 \in A_2, \dots, p_x \in A_x, \dots, p_t \in A_t. \quad (1)$$

The number of elements in each of the sets belonging to one aggregate will be the same and equal to the number of SMEs in the aggregate. The number of elements included in the set is called its power. The sets that characterize the indicators of SMEs aggregates are finite, since the number of their elements is limited and equal to t .

The power of each of the sets corresponding to the performance indicators of a particular aggregate of SMEs is determined by the number of entrepreneurial structures included in this aggregate. The power of some sets corresponding to SMEs aggregates formed by industry characteristics is presented in table 1. The corresponding empirical data on the number of small and medium enterprises and individual entrepreneurs are provided according to official statistics Russia [2].

Table- I: The power of some sets

Types of economic activity	The number of actually operating small and medium enterprises	The number of actually operating individual entrepreneurs
1. Agriculture, forestry, hunting, fishing and fish farming	53228	330396
2. Mining	10416	723
3. Manufacturing	224530	423736
4. Provision of electricity, gas and steam; air conditioning	11929	2711
5. Water supply; water disposal, organization of waste collection, pollution elimination activities	17087	10277
6. Construction	338467	254204

7. Wholesale and retail trade; repair of motor vehicles and motorcycles	926215	3048555
8. Transportation and storage	174243	535315
9. Hotels and catering activities	75446	229907
10. Information and communications activities	88261	102943
11. Real estate	206316	231708
12. Professional, research and technical activities	239700	128129
13. Administrative activities and accompanying services	128393	44358
14. Education	9836	28008
15. Activities in the field of health and social services	46413	59110
16. Activities in the field of culture, sports, leisure and entertainment	24332	280972

Source: own calculations based on official statistics

The data given in the table 1 show that the total number of business structures for most types of activities is measured by tens and hundreds of thousands. The minimum values for small and medium enterprises are in the field of education (9836), and for individual entrepreneurs – in mining (723). Even these minimum values indicate a large number of elements in the corresponding sets.

IV. RESULT

Operations on sets can be used to characterize the relationships between indicators of different aggregates of SMEs. The union of several sets is known to be the set that includes all the elements of the united sets.

The union of the sets characterizing the indicators of SMEs aggregates formed by size and organizational characteristics can be represented as follows:

$$P_{SME} = A_{SE} \cup A_{ME} \cup A_{IE}, \quad (2)$$

where P_{SME} – a set describing the indicators of the aggregate of SMEs in Russia as a whole;

A_{SE}, A_{ME}, A_{IE} – sets that characterize the indicators of small enterprises, medium enterprises and individual entrepreneurs, respectively.

The union of the sets characterizing the indicators of SMEs aggregates formed by territorial characteristics has the form:

$$P_{SME} = A_1 \cup A_2 \cup \dots \cup A_i \cup \dots \cup A_n = \bigcup_{i=1}^n A_i, \quad (3)$$

where A_i – a set describing the indicator of the aggregate of SMEs in the i - region of Russia.

The union of sets that characterize the indicators of SMEs aggregates formed by industry (for the first 6 types of economic activity shown in table 01) can be represented as follows:

$$P_{SME} = B_1 \cup B_2 \cup B_3 \cup B_4 \cup B_5 \cup B_6, \quad (4)$$

where B – sets describing indicators of aggregates of SMEs engaged in six economic activities mentioned above.

When classifying SMEs by a certain type of economic activity, each enterprise (entrepreneur) should be assigned to only one set prevailing for it.

The above formulas can be used in the analysis of relationships for any of the considered indicators. It should be noted that, by definition, the united elements cannot include identical elements.

Similarly, the sets describing the indicators of the aggregates of SMEs operating in a particular region can also be represented in the form of unions according to the three indicated criteria. The difference is that the indicators of aggregates of SMEs in municipalities that are part of the corresponding region are considered on a territorial basis. The set characterizing the indicator of the aggregate of SMEs in a particular region can be represented in three variants using the symbols given above.

The union of the sets describing the indicators of the aggregates of SMEs in the region of Russia, formed by the size-organizational characteristics, can be represented as follows:

$$A_{iSME} = A_{iSE} \cup A_{iME} \cup A_{iIE}, \quad (5)$$

where A_{iSME} – a set describing the indicator of the aggregate SMEs in the i -region of Russia;

$A_{iSE}, A_{iME}, A_{iIE}$ – sets characterizing indicators of aggregates of small enterprises, medium enterprises, and individual entrepreneurs in the i - region, respectively.

The union of the sets describing the indicators of the aggregates of SMEs formed on a territorial basis has the form:

$$A_{iSME} = A_{i1} \cup A_{i2} \cup \dots \cup A_{ij} \cup \dots \cup A_{ik} = \bigcup_{j=1}^k A_{ij}, \quad (6)$$

where A_{ij} – a set characterizing the indicator of the aggregate of SMEs in the j - municipality of the i - region of Russia.

The union of sets describing the indicators of the aggregates of SMEs formed by industry characteristic can be represented as follows:

$$A_{iSME} = B_{i1} \cup B_{i2} \cup B_{i3} \cup B_{i4} \cup B_{i5} \cup B_{i6}, \quad (7)$$

where B_i – a set characterizing the indicator of the aggregate of SMEs in the i - region, engaged in the first six types of economic activity, and B_{i3} - corresponds to SMEs, engaged in manufacturing. When conducting research, along with the above sets describing the indicators of aggregates of SMEs, we can also consider the united sets based on other classifications (for example, aggregates of SMEs by Federal districts, by large cities, geographical and climatic zones, etc.).

The intersection of several sets is the set composed of elements included in all these sets. Next, we consider some examples of sets that describe the indicators of SMEs aggregates formed with the help of logical intersection operation (using the symbols given above):

- a set describing the indicators of the aggregate of small enterprises of the country engaged in construction

$$C_{SE6} = A_{SE} \cap B_6; \quad (8)$$

- a set describing the indicators of the aggregate of medium enterprises of the country engaged in trade

$$C_{ME7} = A_{ME} \cap B_7; \quad (9)$$

- a set describing the indicator of the aggregate of individual entrepreneurs of the i - region engaged in real estate operations

$$C_{iIE11} = A_{iIE} \cap B_{i11} = A_{iE} \cap A_i \cap B_{i11}; \quad (10)$$

- a set describing the indicator of the aggregate of small enterprises in the j - municipality of the i - region engaged in manufacturing

$$C_{ijSE3} = A_{iSE} \cap A_{ij} \cap B_{i3}; \quad (11)$$

- a set describing the indicator of the aggregate of SMEs in the j - municipality of the i - region, which provide transport services

$$C_{ijSME8} = A_{ijSME} \cap B_{i8}. \quad (12)$$

V. DISCUSSION

Modeling the activities of SMEs aggregates is based on numerous indicators. It seems logical to distinguish three types of indicators. The first type – absolute indicators that characterize the total values of the considered values for a set of business structures. As examples, we can specify such indicators as the volume of production, the number of employees, the amount of investment, the cost of fixed assets, the total payroll for the aggregate of business structures. As indicated earlier, each of the sets describes a specific indicator for all the SMEs in the aggregate. Therefore, the absolute value of this indicator is calculated by summing all the elements of the corresponding set. If the set corresponding to the SMEs aggregate is obtained by combining other sets, then the absolute value of the indicator is calculated by summing the indicators describing all the sets included in the union.

The second type of indicators – average indicators that characterize the average values of the considered values for the aggregate of business structures. As examples, we can indicate the average output, the average investment, the average value of fixed assets per SME or employee, and the average number of employees per SME. The average indicators are calculated by dividing the absolute values of the indicators by the number of SMEs or the number of their employees, respectively, for the considered aggregate of business structures.

The third type – specific indicators that are divided into three varieties. The first of them describes the shares of individual aggregates of SMEs in their union (characteristic of the internal structure of SMEs). As an example of indicators describing the shares of individual aggregates of SMEs in their unions, we can specify the shares attributable to small enterprises, medium enterprises, individual

entrepreneurs in the total indicators for SMEs aggregate. Similarly, shares attributable to each type of economic activity or shares for each territorial entity can be defined. The second type of specific indicators reflects the role and place of SMEs aggregates in the Federal, regional and municipal economies. As an example of such indicators, we can calculate the share of production volumes of SMEs, investments in them, the level of SMEs participation in the contract system, the level of entrepreneurial activity in the overall indicators of the national economy, by region, as well as by individual municipality. The values of such an indicator are calculated by dividing the absolute value of the indicator for the aggregate of SMEs by the value of a similar indicator for all enterprises and organizations operating in the considered territory or in a certain type of economic activity. The third variety describes specific indicators of the aggregate of SMEs based on a certain number of economically active population or on the total number of inhabitants in a certain territory. For example, the number of SMEs, their production volumes, the number of employees per 10 thousand people of the economically active population or 10 thousand inhabitants of the corresponding territory.

The absolute values of indicators describing the activities of SMEs aggregates by region are not always sufficiently informative, since they do not allow a comparison of indicators of different regions. Therefore, when conducting research related to comparing the level of development of entrepreneurship in the regions, it is advisable to use the average and specific values of indicators. It should be noted that the calculations based on the arithmetic averages of indicators for the regions give biased estimates that do not reflect the patterns typical for most of its regions. These estimates are biased towards large regions. For example, the Federal cities of Moscow and St. Petersburg account for almost 20 % of the turnover of all SMEs in the country, while most other regions do not account for more than 2 % of the turnover. Therefore, along with the study of arithmetic averages, it seems logical to consider the patterns describing the average values for all SMEs aggregates in each of the regions of the country.

A large number of different factors influence the performance indicators of SMEs aggregates. There is a kind of dualism. On the one hand, there are factors that determine the similarity and proximity of average and specific values of indicators for most regions of the country. On the other hand, as noted earlier, the accumulated experience of entrepreneurship shows a significant differentiation of indicators of aggregates of SMEs operating in different regions of Russia.

The main factors that determine the similarity and proximity of indicators may include:

- unified Federal legislative framework that defines the activities of business structures;
- general legal acts and regulations that define the procedure for registration of SMEs, their interaction with regulatory and control bodies, the banking system;
- current state system of taxation, social payments, as well as accounting and reporting;

- general history of formation and stages of development of small and medium enterprises;
- the same type of regulatory tools, forms and methods of support of entrepreneurship;
- the same main types of activities in which SMEs specialize;
- functioning, as a rule, in markets of perfect and monopolistic competition;
- participation in procurement in accordance with the current contract system.

The existing differentiation of the values of indicators of SMEs aggregates in different regions is due to both objective and subjective factors.

The main objective factors are:

- geographical location and climatic conditions;
- level of socio-economic development of the region;
- branch structure of the regional economy;
- infrastructure development;
- existing institutional framework.

The main subjective factors determining the differences in the performance indicators of SMEs are:

- mentality and national characteristics of the population;
- level of training of management and production personnel;
- strategy and tactics of owners and management;
- attitude to SMEs by regional and municipal authorities;

It should be noted that both objective and subjective factors that determine differences in indicators can act in different directions, that is, lead to an increase or decrease in the values of indicators.

VI. CONCLUSION

The study showed that the number of small and medium enterprises in certain industries and regions of Russia amounts to tens, and in some cases, hundreds of thousands. Therefore, a new methodological approach based on the use of such a mathematical apparatus as set theory was proposed to assess the indicators that characterize the activities of small and medium-sized enterprises. It allows to improve the process of formation and analysis of relevant databases, using computer economic and mathematical models. The main results of the work are as follows:

- methodological foundations for analyzing SMEs performance indicators using the aggregates formed according to three criteria (size-organizational, sectoral and territorial) are developed;
- the possibility of describing the indicators characterizing the SMEs aggregates and the relationships between these aggregates using the mathematical apparatus of set theory is shown;
- a typology of performance indicators for SMEs is proposed, which include three types of indicators: absolute, average and specific (with three varieties);
- factors that determine the similarity of the values of indicators for SMEs aggregates, as well as objective and subjective factors affecting the differentiation of indicators are considered;
- the use of average and specific indicators to compare the level of development of SMEs by regions and sectors, as well as to identify the imbalances between them, is proposed.

The results of the study can be used to develop technology for processing data on the activities of business entities, as a tool for analyzing economic activity and making decisions. They will help to solve the tasks identified in the Strategy for the Development of the Information Society in the Russian Federation for 2017-2030. The results are of interest when conducting research on the problems of SMEs. They make it possible to establish patterns and trends in the development of various aggregates of SMEs, substantiate proposals and recommendations for improving their functioning on the basis of the characteristics specific to particular aggregates, and provide a differentiated approach to solving problems of state regulation of entrepreneurship.

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AUTHORS PROFILE



I. S. Pinkovetskaia, Ph.D., Associate Professor, Department of Economic analysis and state management, Ulyanovsk State University, Ulyanovsk, Russia Federation. From 2006 teaching masters and bachelors in Institute Economics and Business Ulyanovsk State University. Her research interests include state and municipal management, entrepreneurship, sociology, regionalistic, clusters analysis, statistics, economics and mathematical modeling, contract system in Russia, risk management, small and medium business, entrepreneurship support, investment management, sectoral development, spatial economics, municipal economics, employees wage, anticrisis management, gender economic relationship, entrepreneurship motivation.

In recent years, she has published more than 20 articles in journals included in the Scopus and Web of Science databases. Published more than 200 articles in journals published in Russia.



I. N. Nikitina, Ph.D., Associate Professor, Department of Linguistics and Foreign Business Communication, Institute of Management Samara State University of Economics, Samara, Russia Federation. From 2014 teaching masters and bachelors in Samara State University of Economics.

Her research interests include intercultural business communication, entrepreneurship, sociology, social responsibility of business, economics and mathematical modeling, contract system in Russia, small and medium business, entrepreneurship support, investment management, education management, gender economic relationship, entrepreneurship motivation, state and municipal management. Participated in more than 60 research papers and 2 books published in Russia and abroad including journals from Scopus and Web of Science databases.



T.V. Gromova, Grand Ph.D., Professor, Department of Linguistics and Foreign Business Communication, Institute of Management Samara State University of Economics, Samara, Russia Federation. From 2010 teaching masters and bachelors in Samara State University of Economics.

Her research interests include new technologies in education, entrepreneurship, sociology, social responsibility of business, economics and mathematical modeling, contract system in Russia, small and medium business, entrepreneurship support, investment management, education management, gender economic relationship, entrepreneurship motivation, state and municipal management. Participated in more than 100 research papers published in Russia and abroad including journals from Scopus and Web of Science databases.