USING MAMDANI FUZZY INFERENCE ALGORITHMS TO DETERMINE THE LEVEL OF STABILITY OF THE SELF-EMPLOYED MARKET IN THE RUSSIAN FEDERATION

USANDO ALGORITMOS DE INFERÊNCIA MAMDANI FUZZY PARA DETERMINAR O NÍVEL DE ESTABILIDADE DO MERCADO INDEPENDENTE NA FEDERAÇÃO RUSSA

USO DE ALGORITMOS DE INFERENCIA FUZZY DE MAMDANI PARA DETERMINAR EL NIVEL DE ESTABILIDAD DEL MERCADO DE AUTÓNOMOS EN LA FEDERACIÓN DE RUSIA

Andrei Plotnikov
plotnikov.a.v@list.ru
http://orcid.org/0000-0001-5777-3969
Perm National Research Polytechnic University Russia, Russian Federation

Taras Vorobets
vorobets.taras@bk.ru
http://orcid.org/0000-0003-1759-0150
The Institute of Economics The Ural Branch of the Russian Academy of Sciences, Perm Branch
Russian Federation

Anna Urasova
anna-urasova@mail.ru
http://orcid.org/0000-0002-0598-5051
The Institute of Economics The Ural Branch of the Russian Academy of Sciences, Perm Branch
Russian Federation

ABSTRACT

The study develops an understanding of the environment for the functioning of the self-employed market and provides its current assessment. A model based on the theory of fuzzy sets is used to determine the level of stability of the functioning of the self-employed market in the Russian Federation, specifically through Mamdani fuzzy inference algorithms. The survey sample includes 12 experts, who responded to the survey questions (N = 22) voluntarily. Calculations for the study are performed in Matlab. The results obtained give evidence that the level of stability of the Russian self-employed market equals 0.5, which falls into the third interval of the five-level classification. This set is characterized by the following linguistic definition – the functioning of the market is stable, and its characteristics correspond to the "satisfactory (average)" level. This suggests that the market for the self-employed in the Russian Federation has fairly good potential for growth, as there are no signs of its slowdown.

Keywords: employment; self-employment; freelancing, self-employed market, unemployment, stability, Fuzzy Logic.

RESUMO

O estudo desenvolve uma compreensão do ambiente para o funcionamento do mercado de trabalho autônomo e fornece sua avaliação atual. Um modelo baseado na teoria dos conjuntos fuzzy é utilizado para determinar o nível de estabilidade do funcionamento do mercado autônomo na Federação Russa, especificamente através de algoritmos de inferência fuzzy Mamdani. A amostra da pesquisa inclui 12 especialistas, que responderam às perguntas da pesquisa (N = 22) voluntariamente. Os cálculos para o estudo são realizados em Matlab. Os resultados obtidos evidenciam que o nível de estabilidade do mercado de autônomos russo é igual a 0,5, que se enquadra no terceiro intervalo da classificação de cinco níveis. Este conjunto é caracterizado pela seguinte definição linguística – o funcionamento do mercado é estável, e suas características correspondem ao nível "satisfatório (médio)". Isso sugere que o mercado de autônomos na Federação Russa tem um potencial de crescimento bastante bom, pois não há sinais de desaceleração.

Palavras-chave: emprego; Empregado por conta própria; freelance, mercado autônomo, desemprego, estabilidade, Lógica Fuzzy.

RESUMEN

El estudio desarrolla una comprensión del entorno para el funcionamiento del mercado de trabajadores por cuenta propia y proporciona su evaluación actual. Se utiliza un modelo basado en la teoría de conjuntos difusos para determinar el nivel de estabilidad del funcionamiento del mercado de autónomos en la Federación Rusa, concretamente a través de los algoritmos de inferencia difusa de Mamdani. La muestra de la encuesta incluye 12 expertos, que respondieron a las preguntas de la encuesta (N = 22) voluntariamente. Los cálculos para el estudio se realizan en Matlab. Los resultados obtenidos evidencian que el nivel de estabilidad del mercado de autónomos ruso es igual a 0,5, lo que se sitúa en el tercer intervalo de la clasificación de cinco niveles. Este conjunto se caracteriza por la siguiente definición lingüística: el funcionamiento del mercado es estable y sus características

corresponden al nivel "satisfactorio (promedio)". Esto sugiere que el mercado de trabajadores por cuenta propia en la Federación Rusa tiene un potencial de crecimiento bastante bueno, ya que no hay signos de desaceleración.

Palabras clave: empleo; auto-empleo; freelance, mercado de autónomos, paro, estabilidad, Fuzzy Logic.

1. INTRODUCTION

At the time of economic downturns, geopolitical instability, and increasing risks amid the global pandemic, scholarly thought is faced with the need to revisit the standard operating mechanisms of familiar processes. The ongoing digitalization of the global business space is shaping new institutional conditions and opportunities for the development of the global economy. Transformational processes have taken place in the field of labor relations, too, especially with regard to full-time employment. It should be noted that this habitual for most understanding of employment as the presence of an employment contract, a certain place of work, including premises for the performance of labor functions, regulated working time and rest time, a fixed wage, etc. has already undergone major changes.

At the same time, it should be borne in mind that employment is not an isolated economic concept but one that is closely interconnected with not only economic but also social processes. In this vein, Yu. N. Popov and A.V. Shevchuk (2005) examine the relationship between employment and unemployment, justifying a clear distinction between these categories. In doing so, the authors rely on the classical understanding of these concepts, arguing that workers, as a rule, rarely change both the sphere of application of their labor (profession) and the place of work (organization, enterprise) in the course of their working career. In our view, this approach is constructed based on the absence of global shocks (instability in global politics, emerging outbreaks of infectious diseases) and the existence of a clearly structured public policy in the field of social support for the employed population, but at present, it already needs to be reconsidered. Many states have found themselves unable to provide adequate social support for the employed population during the global pandemic of COVID-19. Meanwhile, the self-employed do lose part of their income due to the COVID-19 pandemic (Wolfe & Patel, 2021). S. C. Mindes and P. Lewin (2021) claim that age influences

incapacity to work due to the COVID-19 pandemic but is less of a factor among the self-employed. In the same study, self-employed employers are found to be hit by the COVID-19 pandemic harder and recover slower.

According to A. N. Pokida and N. V. Zybunovskaya (2019), the general trend in today's labor market is a growing prevalence of non-standard employment resulting from the mobility of labor resources and the reduced dependence of the employee on the employer. The authors note that non-standard forms of employment are difficult for the state to control, often coming as "shadow" employment that is not reflected in official documents. At the same time, another area that differs greatly in its characteristics from standard employment and lacks legal certainty is self-employment. In a different study, the number of self-employed is projected to exceed the number of hired workers (Struckell et al., 2022).

It is worth noting that the self-employed are currently represented by various groups of citizens, particularly in terms of the formalization of their employment. Some self-employed individuals work on an informal basis, paying neither taxes nor insurance fees. In the meantime, they enjoy free use of public goods. As a result of this, the state budget falls short of a portion of possible revenues, while the self-employed themselves, staying in the "shadows", deprive themselves of the right to receive an insurance pension in the future by not making contributions to the pension fund and keeping their length of service unregistered. Thus, the primary reasons justifying the need for regulation of the self-employed market by the state are the following. First and foremost, the need for additional tax revenues to the state budget and the reduction of the burden on the social off-budget funds. Second, the integration of the self-employed into state economic processes can contribute to the development of their entrepreneurial initiative due to broader instrumental opportunities to support them (Giménez-Nadal et al., 2022).

The described problem calls for further, more in-depth study of the processes of formation of development of Russia's self-employed market. This paper presents a study of the preconditions for the formation of the self-employed market in the Russian Federation and offers its assessment based on the fuzzy set theory. Based on the obtained findings, we propose ways to further develop the market for the self-employed in the Russian Federation.

In continuation of the introductory part, it appears necessary to consider the state of unemployment in the Russian Federation, since this specific parameter shapes the main preconditions (background) for the development of the self-employed market (the availability of vacancies, qualifications, competition for positions, average wage levels, wages of people already employed, working conditions, and much more). This argument is further supported by the results of the conducted survey, as the most common motives for freelancing or self-employment (according to the respondents) include: striving for additional income – 42%, unwillingness to work in an organization – 21%, and job loss – 20% (Figure 1).
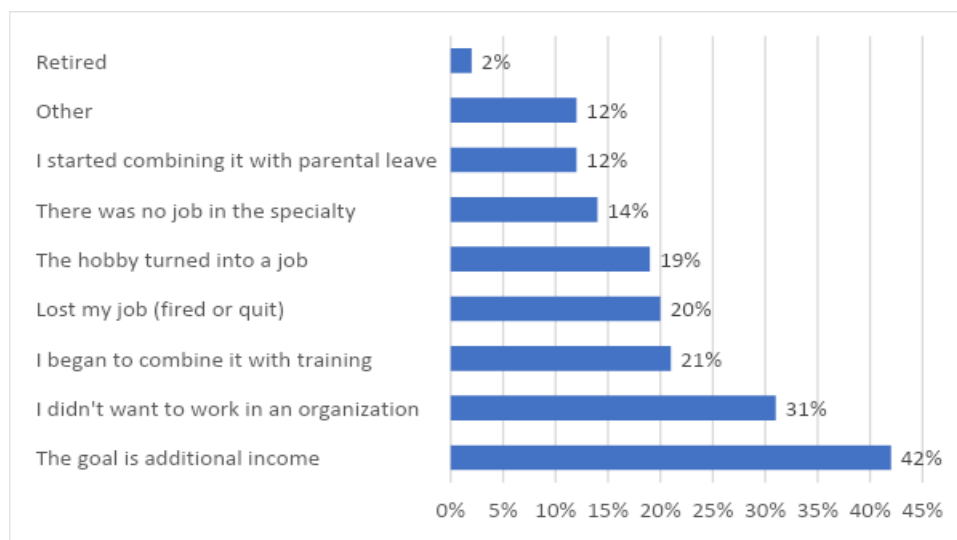

Figure 1. Results for the question "Why did you become a freelancer?" (Link to the survey)

Analyzing the official statistics, it is worth noting that the unemployment rate exhibits a downward trend in the short term (from 6.3 in 2020 to 4.3 at the end of 2021), but a slight linear upward trend is observed from the beginning of 2017 to the end of 2021 (Figure 2).
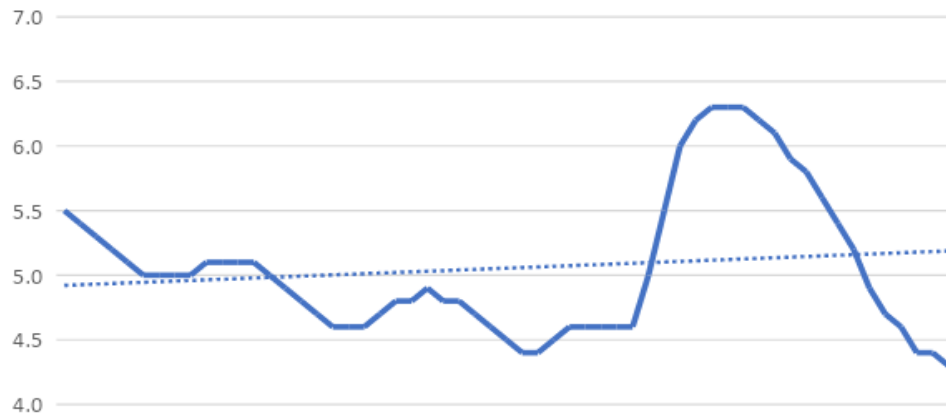
Figure 2. Unemployment rate of the population aged 15 and older from 2017 to 2021 in the Russian Federation (Rosstat)

Thus, we can argue about the need to not only develop a comprehensive policy of support for businesses but also to introduce a range of measures to stimulate the development of the self-employed market in order to progressively increase the tax base, which is a vitally important aspect in times of economic crises and restraints. Continuing the research, we also examine the dynamics of the structure of the employed population by the type of economic activity (Figure 3). The data obtained (from 2005 to 2020) are compared with the sectoral structure of the GDP of the Russian Federation by means of a topological description of economic processes.
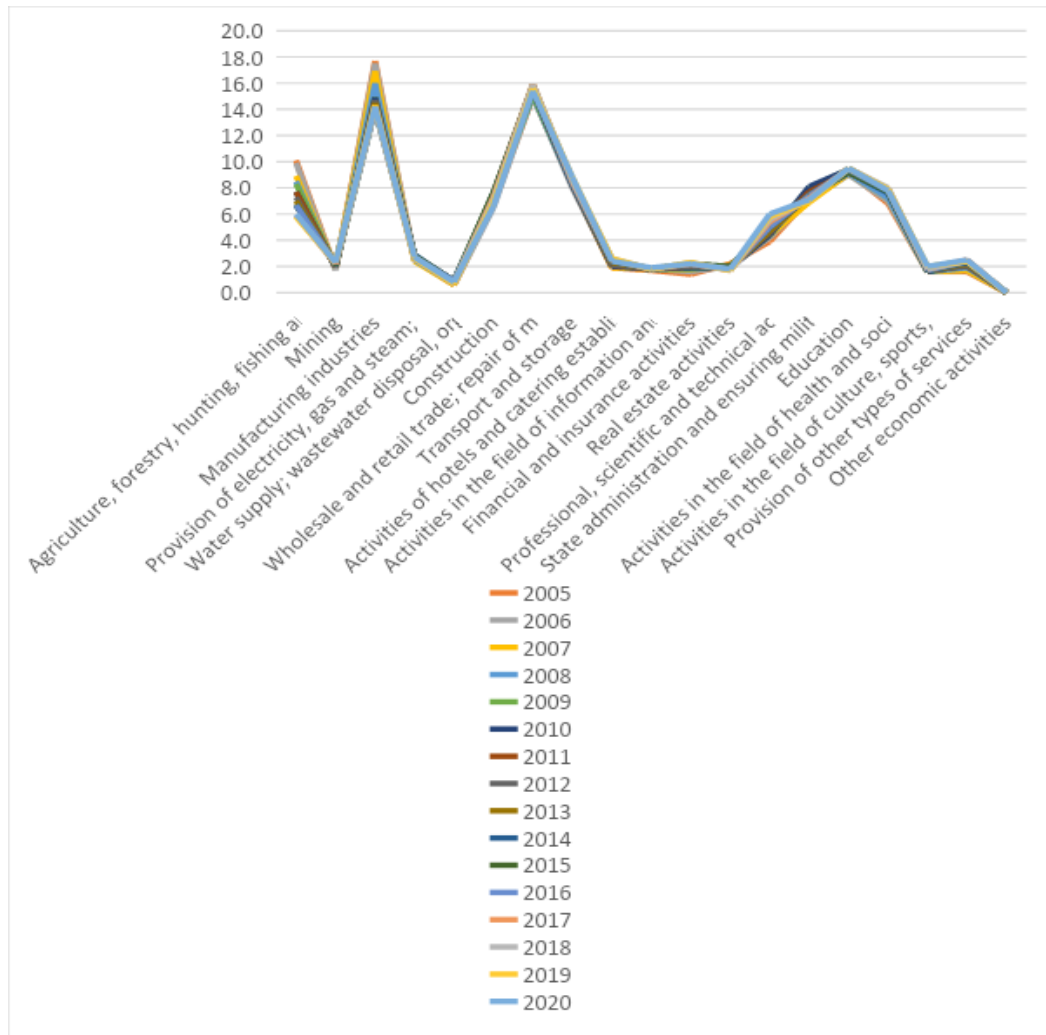
Figure 3. The structure of the employed population by types of economic activity in the main job, on average for the year (Rosstat)

Source: research data

The results are indicative of the formation of prerequisites for the development of the self-employed market as one of the effective mechanisms for reducing unemployment and potentially increasing total added value. According to the official statistics of the Tax Inspectorate of the Russian Federation, at the start of 2022, there were over 4,000,000 registered self-employed citizens and their total income over the time of operation of the preferential tax regime has exceeded 882 billion rubles. The self-employed have formed more than 610 million checks (the average check being 1'446 rubles). The most popular occupations are cab services, as well as repairs and marketing, deliveries of goods, and

apartment rentals. The highest-paid professions are in the IT-sphere, lawyers, consultants, designers, etc. 42% of the respondents are women and 58% are men. (Federal Tax Service of Russia, 2022).

Currently, the activities of self-employed individuals are governed by Federal Law No. 428-FZ "On Conducting an Experiment to Establish a Special Tax Regime 'Tax on Professional Income'" (Russian Federal Law No. 428, 2019). A self-employed citizen is a physical person (or an individual entrepreneur who has chosen the new tax regime – tax on professional income) who receives income from the use of property or from their work, in which they do not have an employer and or hire other workers under labor contracts. This regime is valid until December 31, 2028. During this period, tax rates will not change.

However, the scientific literature does not have a universally shared opinion on this economic concept. A. N. Pokida and N. V. Zybunovskaya note that some researchers view this concept in the broad sense, in which its essence is independent work. Therefore, under this approach, all non-hired workers are classified as self-employed. For example, E. A. Abramova defines the self-employed as "owners of small and micro businesses, entrepreneurs engaged in self-employment without establishing a legal entity, those employed in households" (Abramova, 2012). This formal approach essentially combines into one general category completely different groups of workers with different goals and principles of activity.

The broad view is also shared by such researchers as N. M. Volovskaya et al., who consider self-employment to be primary for entrepreneurship, as it bears such properties as "activity, initiative, independence, risk, creativity, and organization" (Volovskaya et al., 2018).

E. G. Krylova considers self-employed people as entrepreneurs, although with certain specific features, emphasizing the informal nature of their activities: "they are natural persons engaged in self-employment for their profit as a means of subsistence, in this regard, there is no need for them to get a job" (Krylova, 2017).

E. S. Kryukova and V. D. Ruzanova are supporters of a "narrowly-specialized understanding of this category of citizens". The authors hold that a distinction should be made between "individual entrepreneurs (both registered and those carrying out their

entrepreneurial activity without state registration) and self-employed persons who do not have the status of an individual entrepreneur" (Kryukova & Ruzanova, 2018). The concepts of "entrepreneurship" and "self-employment" are differentiated by O. N. Grabova and A. E. Sulogubov, who emphasize the "personal labor participation" of the self-employed: "Self-employed persons are citizens who independently carry out activities based on personal labor participation at their own risk to provide services and perform work for individuals, with the purpose of systematic profit-making; who are not registered as individual entrepreneurs; who do not have hired employees" (Grabova, Sologubov, 2017).

Despite all the similarities and differences, R. Pedersini and D. Coletto define five main categories of self-employment, which are presented in Table 1 (Pedersini, Coletto, 2009):

Table 1
The main categories of self-employment.

Category	Characteristic/Peculiarities
entrepreneurs	run their business with the help of employees
"free professionals"	in order to work in the profession, they must meet specific requirements, comply with regulations and mandatory codes, and often pass examinations to be included in public registries; they can hire workers, but, with some exceptions, usually carry out their activities independently or in collaboration with other professionals and with the help of a limited number of workers, if any
artisans, merchants, and farmers	represent conventional forms of self-employment; these self-employed workers often work with family members and possibly a small number of employees
non-hired workers	workers in skilled but unregulated occupations, sometimes referred to as "new professionals"
self-employed workers	run their business without employees, but sometimes with the help of family members

Source: compiled by the authors based on (Pedersini, Coletto, 2009)

As presented above, the definition of the self-employed is of particular interest to modern researchers. In our opinion, further elaboration of proposals on the development of the self-employed market requires assessing its current state first. Since the functioning of the self-employed market in the Russian Federation started to formalize relatively recently (legislative initiatives have been in force for a little over 4 years), as the main approach to assessing the stability of the market, we propose to use a comprehensive approach, which is most appropriate for the dynamic analysis of the relationship between the components of stability.

2. METHODS

In this study, the structure of the employed population by type of economic activity is proposed to be analyzed using the topological method of describing economic processes inspired by the polymerase chain reaction (PCR) method widely used in molecular biology. It is a method used in laboratories to quickly clone a specific section of deoxyribonucleic acid (DNA), which, in turn, bears a direct analogy to cellular DNA replication in biology and nuclear reactions in physics. It was discovered that the main components of the PCR reaction mixture in many ways have explicit analogs in economics, and that the principle of PCR can be successfully applied to describe economic processes, including step-by-step growth of economic activity and the study of the economic potential of the country as a whole (Vorobets, Oberemok, 2020).

To determine the level of stability of the self-employed market in the Russian Federation in 2021, we employ a model based on the theory of fuzzy sets, namely Mamdani fuzzy inference algorithms (Iancu, 2012; Akgun et al., 2012). The proposed comprehensive approach integrates the information and systemic (systemic modeling) approaches. This specific combination is determined by the structure of the self-employed market since the environment in which they operate is little formalized and a number of its indicators are informational in nature (Vorobets, Tumanova, 2017).

The data for the study were collected via a survey on Google Forms. The respondents for the survey were recruited in communities on the social media platform VKontakte. Participation in the survey was completely voluntary. The survey sample includes a total of 12 people who were working as freelancers at the time of the study or not so long prior. Calculations for the study were performed in Matlab. The expert respondents were university professors (4 experts), specialists on self-employment (researchers studying self-employment problems and working on approaches to its development, 4 experts), and self-employed people themselves (4 experts).

Description of variables

Below, we shall examine the variables adopted for analysis. This section of the paper gives the names of the factors and describes the influence of their content on self-employment according to various studies.

Unemployment rate

Unemployed people are found to be more likely to become small entrepreneurs while working people are more sensitive to wages than the unemployed in their decision to engage in entrepreneurship (da Fonseca, 2021).

The argument of the theory of income choice suggests that the rise in unemployment may lead to increased self-employment activity. The counterargument, in turn, defends the view that growing unemployment rates may reduce the stock of human capital and entrepreneurial talent, causing unemployment rates to build up further (Halicioglu, & Yolac, 2015).

High levels of unemployment lead individuals to turn to self-employment (the "refugee" effect). Then, the opposite effect can occur – high rates of self-employment lead to increased entrepreneurial activity, which reduces unemployment in subsequent periods ("entrepreneurial" effect) (Thurik et al., 2008).

In a study by G. López-Martínez et al. (2021), increased engagement in work tasks is discovered based on the example of self-employed fishermen. This engagement shows itself in resilience shaped by ownership of the basic means of production as well as production relations. As prosperity increases, the self-employed report increased life satisfaction (Wolfe & Patel, 2018). In this context, however, the key factor may not be self-employment, but rather the growing prosperity.

The presence of the main place of employment in the self-employed

High wages greatly reduce the level of entry into entrepreneurship for the employed compared to the unemployed (da Fonseca, 2021). Furthermore, self-employment may have detrimental consequences for the classic labor market (Pritadrajati et al., 2021).

The accessibility of credit to the self-employed

Financial institutions use the size of the company as a core criterion in their lending decisions, which clearly shows how microenterprises are most likely to face a credit crisis (Grashuis, 2021). However, self-employment is the most strongly associated with the improvement of financial status (Dang et al., 2021).

The impact of social protection on self-employment

The informal labor market yields a particular perspective for many developing countries – a situation that goes beyond unemployment and leads to workers' inability to afford to be unemployed. Despite the fact that workers employed in the informal economy are usually classified as employed, this type of employment has no social protection, i.e., no access to pensions, health benefits, and formal training (Pritadrajati et al., 2021).

Self-employment was promoted among welfare recipients as a way out of poverty. Thus, the transition from unemployment to self-employment takes the burden off the state (Danson et al., 2021).

The availability of disposable resources for the activity

The newly self-employed people have the least resource capacities to take risks and responsibilities (Danson et al., 2021).

What can be considered a resource is real estate, which, as shown by research (Xiang et al., 2021), has a significant positive impact on self-employment. Meanwhile, the lack of resources prevents the self-employed from taking responsibility (Danson et al., 2021).

State support

Insufficient state support for the self-employed fails to reduce social and economic risks (Danson et al., 2021). Considering the experience of China, local governments stimulate self-employment in the provinces (Dou et al., 2019). The increase in government EITC benefits has led to an increase in self-employment among married mothers in low-income families (Lim & Michelmore, 2018).

Tax revenues

Continuous reduction of payroll taxation increases the share of workers in the formal economy and reduces the share of the self-employed (Narita, 2020).

Entrepreneurial activity

The methodology of the International Labor Organization recognizes four main groups of self-employment, among which are not only those working individually, but also those using wage labor: "individual entrepreneurs not using wage labor (own-account workers)", "entrepreneurs of unincorporated businesses using wage labor (employers)", as well as members of producers' cooperatives, and contributing family workers. Note that the representatives of the first group are more often referred to as self-employed (Pokida & Zybunovskaya, 2020). Proceeding from this classification, entrepreneurs can be categorized as self-employed. This conclusion would seem obvious, but it is not so obvious for the study of self-employment in the Russian context. Since the essence of self-employment in the Russian Federation lies in a preferential tax regime and Russian law states that a self-employed person cannot have hired workers, an entrepreneur cannot be considered a self-employed person. In addition, Russian legislation establishes an organizational-legal form of an "individual entrepreneur," who may have hired workers. Thus, the category "self-employed" in Russian legislation corresponds to the own-account workers according to the methodology of the International Labor Organization, and by entrepreneurial activity, we understand their initiatives and competence to conduct business or engage in their own activity.

Entrepreneurial behavior has a positive impact on efficiency. IT self-efficacy is a key factor in entrepreneurial behavior (Sultana et al., 2019). It is also established that the survival of small businesses during the COVID-19 pandemic depends on the characteristics of the owner (Grashuis, 2021). Thus, the characteristics of the entrepreneur/self-employed act as entrepreneurial activity.

Financial literacy

A positive relationship is found between financial literacy and self-employment; women with higher levels of financial literacy are more likely to be self-employed than men

(Struckell et al., 2022). However, the transition to self-employment does not always affect income (Stenard, 2019).

3. RESULTS AND DISCUSSION

The methodology of comprehensive assessment with the use of a systemic approach makes it possible to avoid an excessive number of indicators, that is, to form a balanced system that would help prevent violations of the hierarchy of relationships between the components of market functioning stability. The system of indicators allows assessing the actual stability of functioning, identifies factors of change and sources of untapped opportunities. Thus, the comprehensive approach to assessing the stability of the self-employed market through interrelated indicators can be considered a tool for controlling and planning the functioning of the market. The suggested comprehensive approach combines the informational and systemic (system modeling) approaches. This combination is due to the specifics of market functioning, because the environment in which it operates is poorly formalized, and a number of indicators are informational in nature.

An important part of the methodology of assessing the stability of any market structure is an algorithm, which serves as a basis for the architecture of fuzzy inference systems. Several fuzzy inference algorithms with their own specific characteristics and conditions of application have become widely used in practice, namely the Mamdani (Mamdani & Assilian, 1975) and simplified fuzzy inference algorithm. The most appropriate fuzzy inference algorithm for our situation is the Mamdani algorithm. In its essence, it is a generalization of the sequence of stages of stability estimation. We believe that it is capable of displaying the parameters of the original system most thoroughly.

The fuzzy logic inference algorithm uses a generalized inference tree and follows the following sequence of steps:

– monitoring the internal and external environments of market functioning in order to determine the hierarchical structure of factors that affect the stability of its functioning;

– based on the hierarchical structure of influence factors, a cross-cutting system of indicators is formed, which describes the stability of the market (Table 2);

Table 2
Representation of stability via the characteristics of functioning

	Characteristics	K_i	Intermediate characteristics	Z_i	Indicators	x_i	Assessment
Stability	Reliability	K_1	Labor market	Z_1	Unemployment rate	X_1	0.39
					Difference between the average per capita income of the self-employed and hired workers	X_2	0.45
					The presence of the main place of employment	X_3	0.37
			Investment climate	Z_2	Consumer price level	X_4	0.33
					Access to borrowed funds	X_5	0.32
					Availability of state programs	X_6	0.63
			Organizational and legal basis	Z_3	Equality of interaction with natural persons and legal entities	X_7	0.56
					Ease of registration and reporting	X_8	0.62
	Market value	K_2			Competition level	X_9	0.50
					Market development prospects	X_{10}	0.63
	Potential	K_3	Entrepreneurial activity	Z_4	Ability to see a business opportunity and formulate a business idea	X_{11}	0.78
					Financial literacy	X_{12}	0.50
					Ability to recognize and assess economic trends, market trends, and market deficits	X_{13}	0.58
					Population's attitude to risk	X_{14}	0.67
			Resource availability	Z_5	Dependence on fixed assets	X_{15}	0.24
					Starting capital	X_{16}	0.42
					Level of digitalization	X_{17}	0.63
	Efficiency	K_4	Deductions	Z_6	Contributions to pension and social insurance	X_{18}	0.74
					Tax deductions	X_{19}	0.80
			Business metrics	Z_7	The number of checks generated by self-employed people	X_{20}	0.49
					The number of registered self-employed people	X_{21}	0.37
					The volume of tax revenues from the self-employed	X_{22}	0.54

Source: compiled by the authors

– at the next stage, the task is to form an expert group and analyze the consistency of expert opinions to ensure that the expert assessments are sufficiently accurate;

– it is often most convenient to present the system of indicators in the form of a survey used in the assessment, as it allows collecting comparable data from different information sources;

– then, an image or representation of the levels of stability of the self-employed market based on fuzzy logic is developed. The membership function is defined, in our study,

it is a trapezoidal function, where the X axis denotes the value of the integral index (in the range [0;1]), and the Y axis denotes the truth level (the degree of certainty of the event occurrence, also in the range [0;1]). Table 3 gives a brief description of the possible levels of stability of the self-employed market and their analytical expression based on fuzzy logic.

Table 3
Representation of functional stability based on fuzzy logic

Interpretation of the levels of functional stability	Analytical expression of the stability of market functioning based on fuzzy logic
the market is unstable, but there is still a possibility of exit from the "unsatisfactory (marginal)" state	$a1(R) = \|1 \ if \ 0 \le R \le 0.1 \ [22(0.2 - R)] \ 0.1 \le R \le 0.2 \ 0 \ if \ 0.2 \le R \le 1$
the functioning of the market can be slowed down, and if such signs appear, its stability is rated higher than unsatisfactory as "satisfactory (below average)"	$a2(R) = \|0 \ if \ 0 \le R \le 0.1 \ [22(R - 0.1)] \ 0.1 \le R \le 0.2 \ 1 \ if \ 0.2 \le R \le 0.3 \ [22(0.4 - R)] \ 0.3 \le R \le 0.4 \ 0 \ if \ 0.4 \le R \le 1$
market functioning is stable, and its characteristic corresponds to the level "satisfactory (average)"	$a3(R) = \|0 \ if \ 0 \le R \le 0.3 \ [22(R - 0.3)] \ 0.3 \le R \le 0.4 \ 1 \ if \ 0.4 \le R \le 0.5 \ [22(0.6 - R)] \ 0.5 \le R \le 0.6 \ 0 \ if \ 0.6 \le R \le 1$
market functioning is accelerated, and its characteristic corresponds to "satisfactory (above average)"	$a4(R) = \|0 \ if \ 0 \le R \le 0.5 \ [22(R - 0.5)] \ 0.5 \le R \le 0.6 \ 1 \ if \ 0.6 \le R \le 0.7 \ [22(0.8 - R)] \ 0.7 \le R \le 0.8 \ 0 \ if \ 0.8 \le R \le 1$
market functioning is rapid, and its characteristic corresponds to the level "satisfactory (high)"	$a5(R) = \|1 \ if \ 0 \le R \le 0.7 \ [22(R - 0.7)] \ 0.7 \le R \le 0.8 \ 0 \ if \ 0.8 \le R \le 1$

Source: compiled by the authors

The presence of market functioning stability levels formed with the use of fuzzy logic gives the opportunity to identify the calculated indicator with the corresponding interval specified in Table 3 and determine the actual level of market functioning stability, which, in turn, is a prerequisite or justification for the choice of development strategy for the market as a whole.

The actual level of stability of functioning of the self-employed market depends primarily on the sources and quality of primary information, which can be the results of professional participants (statistical and economic), information on qualitative indicators of market functioning and activities of professional participants, analytical indicators of market functioning, conducted sociological research.

It should also be clarified that by sustainability of the self-employed market we mean the integral indicator of its key characteristics, such as reliability, market value, potential, efficiency.

– at the next stage, using the previously proposed system of indicators, we fix the vector of values of input variables. Input variables are linguistic variables that are used in the formation of conditions (fuzzy rules) of fuzzy productions (Table 2).

– next, we formalize the relationships between the input variables, intermediate indicators, characteristics, and the integral indicator of the sustainability of the self-employed market. As a result, a logical inference tree is formed, which traces the hierarchy of input variables: input variables – subclass – class – integral indicator (Figure 4). The hierarchy of indicators by classes, subclasses, and groups is shown in the form of a logical inference tree, which corresponds to a system of relations.
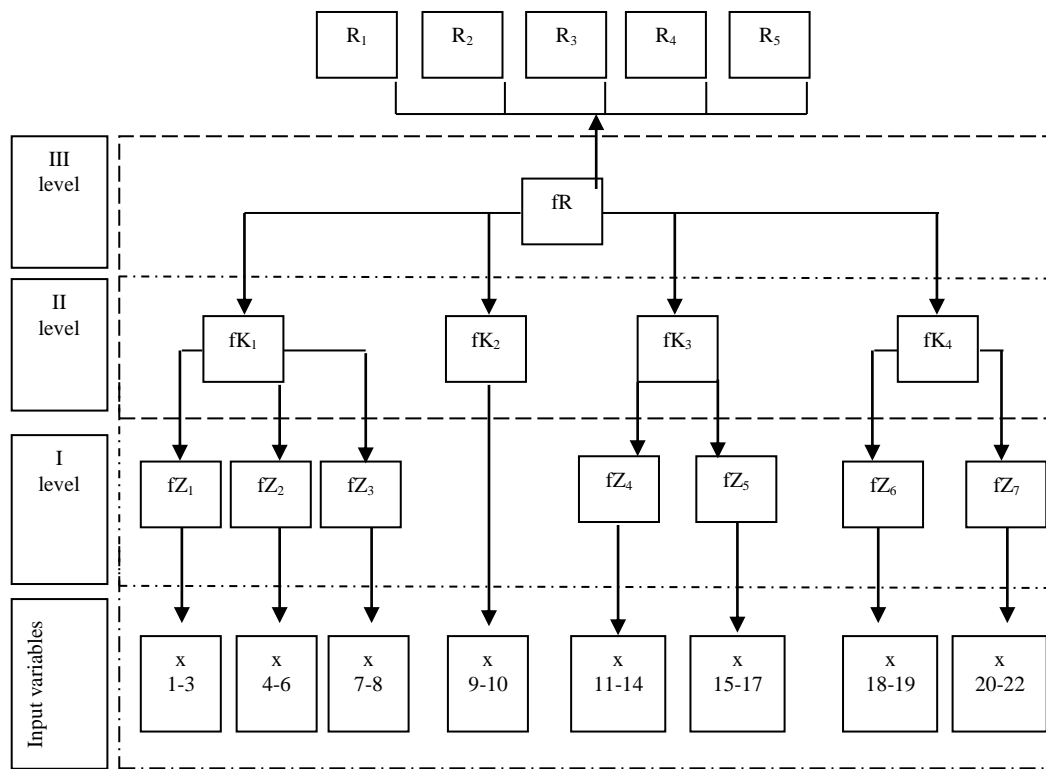
Figure 4. Logical inference tree of the integral stability indicator from the factors affecting it

R_i – output variable (integral indicator) (i=1;5)
K_j – output variable classes (j=1;4)

Z_t – output variable subclasses (j=1;7)

X_g – input variables (g=1;22)

$\{R_1, R_2, \cdots, R_7\}$ – sets of terms to assess the variable R

$\{K_1, K_2, \cdots, K_7\}$ – sets of terms to assess the variable K

$\{Z_1, Z_2, \cdots, Z_7\}$ – sets of terms to assess the variable Z

$\{x_1, x_2, \cdots, x_{22}\}$ – sets of terms to assess the variable X

– further in the course of the study, we determine the values of membership functions of terms-assessments of input variables according to the three-level classifier from the lowest to the highest {low, medium, high}. In the context of fuzzy logic, we understand fuzzification not only as a separate step of fuzzy inference, but also the actual process or procedure of finding the values of membership functions of fuzzy sets (terms) on the basis of input data.

– the next step is determining the membership functions of the terms-assessments of the variables at the next level of the hierarchy (the 1st level of the hierarchy, then the 2nd level, see Figure 4) based on the given system of relations (the procedure continues until the top level – the output variable – is reached) on a three-level classifier from the lowest to the highest {low, medium, high}. The output variable is the linguistic variable used in forming the outputs of the fuzzy production rules.

Let us determine the membership functions of the terms-assessments of the output variable corresponding to the vector of values of input and intermediate variables in the hierarchy:

$$\bigcup_{n=1}^{n_\tau}\left[\left(K_j = K_j^{Nn_\tau}\right) \cap \left(K_j = K_j^{Sn_\tau}\right) \cap \left(K_j = K_j^{Vn_\tau}\right)\right] \to R_j, i = 1, \underline{5}; j = 1, \underline{4}; \tau = 1, \underline{81}$$

$$\bigcup_{n=1}^{n_\tau}\left[\left(x_{gj} = x_{gj}^{Nn_\tau}\right) \cap \left(x_{gj} = x_{gj}^{Sn_\tau}\right) \cap \left(x_{gj} = x_{gj}^{Vn_\tau}\right)\right] \to K_j, gj = 1, \underline{4}; \tau = 1, \underline{81}$$

$$\bigcup_{n=1}^{n_\tau}\left[\left(Z_{tj} = Z_{tj}^{Nn_\tau}\right) \cap \left(Z_{tj} = Z_{tj}^{Sn_\tau}\right) \cap \left(Z_{tj} = Z_{tj}^{Vn_\tau}\right)\right] \to K_j, tj = 1, \underline{7}; \tau = 1, \underline{1179}$$

$$\bigcup_{n=1}^{n_\tau}\left[\left(x_{gj} = x_{gj}^{Nn_\tau}\right) \cap \left(x_{gj} = x_{gj}^{Sn_\tau}\right) \cap \left(x_{gj} = x_{gj}^{Vn_\tau}\right)\right] \to Z_1, gt = 1, \underline{3}; \tau = 1, \underline{27}$$

$$\bigcup_{n=1}^{n_\tau}\left[\left(x_{gj} = x_{gj}^{Nn_\tau}\right) \cap \left(x_{gj} = x_{gj}^{Sn_\tau}\right) \cap \left(x_{gj} = x_{gj}^{Vn_\tau}\right)\right] \to Z_2, gt = 1, \underline{3}; \tau = 1, \underline{27}$$

$$\bigcup_{n=1}^{n_\tau}\left[\left(x_{gj} = x_{gj}^{Nn_\tau}\right) \cap \left(x_{gj} = x_{gj}^{Sn_\tau}\right) \cap \left(x_{gj} = x_{gj}^{Vn_\tau}\right)\right] \to Z_3, gt = 1, \underline{2}; \tau = 1, \underline{9}$$

$$\bigcup_{n=1}^{n_\tau}\left[\left(x_{gj} = x_{gj}^{Nn_\tau}\right) \cap \left(x_{gj} = x_{gj}^{Sn_\tau}\right) \cap \left(x_{gj} = x_{gj}^{Vn_\tau}\right)\right] \to Z_4, gt = 1, \underline{4}; \tau = 1, \underline{81}$$

$$\bigcup_{n=1}^{n_\tau}\left[\left(x_{gj} = x_{gj}^{Nn_\tau}\right) \cap \left(x_{gj} = x_{gj}^{Sn_\tau}\right) \cap \left(x_{gj} = x_{gj}^{Vn_\tau}\right)\right] \to Z_5, gt = 1, \underline{3}; \tau = 1, \underline{27}$$

$$\bigcup_{n=1}^{n_\tau}\left[\left(x_{gj} = x_{gj}^{Nn_\tau}\right) \cap \left(x_{gj} = x_{gj}^{Sn_\tau}\right) \cap \left(x_{gj} = x_{gj}^{Vn_\tau}\right)\right] \to Z_6, gt = 1, \underline{2}; \tau = 1, \underline{9}$$

$$\bigcup_{n=1}^{n_\tau}\left[\left(x_{gj} = x_{gj}^{Nn_\tau}\right) \cap \left(x_{gj} = x_{gj}^{Sn_\tau}\right) \cap \left(x_{gj} = x_{gj}^{Vn_\tau}\right)\right] \to Z_7, gt = 1, \underline{4}; \tau = 1, \underline{81}$$

$$\bigcup_{\tau=1}^{81}\left[\bigcap_{g=1}^{20}\left(x_g = x_g^{N_\tau}\right) \cap \left(x_g = x_g^{S_\tau}\right) \cap \left(x_g = x_g^{V_\tau}\right)\right] \to X = X_A,$$

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Describing expert information about the ratio:

$$R_i = \int_W \frac{a^{R_i(W)}}{\omega} \quad R_i = \int_W \frac{\alpha^{R_i(W)}}{\omega} \quad , (i=1;\boxed{5}), \ \omega \epsilon W \ \omega \in W$$

$$K_i = \int_{U_X} \frac{a^{K_j(U_X)}}{\upsilon} \quad R_i = \int_W \frac{\alpha^{R_i(W)}}{\omega} \quad , K_j = \int_{U_X} \frac{\alpha^{K_j(U_x)}}{x} \quad (j=1;\boxed{4}), \quad x \in U_X \ \upsilon \epsilon U_X,$$

$$Z_i = \int_{Q_X} \frac{a^{Z_j(Q_X)}}{q_X} \quad R_i = \int_W \frac{\alpha^{R_i(W)}}{\omega} \quad , Z_t = \int_{Q_X} \frac{\alpha^{Z_t(Q_x)}}{q_x} \quad (t=1;\boxed{7}), \ q_X \epsilon Q_X,$$

$$x_g = \int_{X_A} \frac{a^{X_g(X_A)}}{x} \quad R_i = \int_W \frac{\alpha^{R_i(W)}}{\omega} \quad , x_g = \int_{X_A} \frac{\alpha^{x_g(X)}}{x} \quad (g=1;\boxed{22}), \ x_g = X_A,$$

where W – the universal indicator set by R, Ri $\in$ W i=1;$\boxed{5}$;
Ux – the universal indicator set by K, Kj$\in$ Ux, j=1;$\boxed{4}$;
Qx – the universal indicator set by Z, Zt$\in$ Qx, t=1;$\boxed{7}$;
XA – the universal indicator set by x, xg$\in$ XA g=1;$\boxed{22}$;
αRi* (x) – the membership function of the variable x to the fuzzy term Ri*.

– Next, according to the algorithm, we determine the exact numbers, values of the membership functions, selecting the one that corresponds to its maximum value:

$$a^{R_i}(K_1, K_2, K_3, K_4) = \left\{ \left[a^{K_j^{ni}}(K_j) \right] \right\},$$
$$a^{K_1}(Z_t) = \left\{ \left[a^{Z_{tj}^{ni}}(Z_{tj}) \right] \right\},$$
$$a^{Z_1}(x_1, x_2, x_3) = \left\{ \left[a^{x_{gt}^{n\tau}}(x_{gt}) \right] \right\},$$
$$a^{Z_2}(x_4, x_5, x_6) = \left\{ \left[a^{x_{gt}^{n\tau}}(x_{gt}) \right] \right\},$$
$$a^{Z_3}(x_7, x_8) = \left\{ \left[a^{x_{gt}^{n\tau}}(x_{gt}) \right] \right\},$$
$$a^{K_2}(x_7, x_8) = \left\{ \left[a^{x_{gt}^{n\tau}}(x_{gt}) \right] \right\},$$
$$a^{K_3}(Z_t) = \left\{ \left[a^{Z_{tj}^{ni}}(Z_{tj}) \right] \right\},$$
$$a^{Z_4}(x_{11}, x_{12}, x_{13}, x_{14}) = \left\{ \left[a^{x_{gt}^{n\tau}}(x_{gt}) \right] \right\},$$
$$a^{Z_5}(x_{15}, x_{16}, x_{17}) = \left\{ \left[a^{x_{gt}^{n\tau}}(x_{gt}) \right] \right\},$$
$$a^{K_4}(Z_t) = \left\{ \left[a^{Z_{tj}^{ni}}(Z_{tj}) \right] \right\},$$
$$a^{Z_6}(x_{18}, x_{19}) = \left\{ \left[a^{x_{gt}^{n\tau}}(x_{gt}) \right] \right\},$$
$$a^{Z_7}(x_{20}, x_{21}, x_{22}) = \left\{ \left[a^{x_{gt}^{n\tau}}(x_{gt}) \right] \right\},$$

– in the next step, the fuzzy number defined by the set of values of the previously obtained clear numbers and obtained at the output of the algorithm must be defuzzified, that is, it must be given a single numerical value. In our case, the method of center of gravity is used. The analytical expression of the center of gravity method takes the following form:

$$\tilde{R} = \{\frac{a^{R_1}(K_1, K_2, K_3, K_4)}{R_1}, \frac{a^{R_2}(K_1, K_2, K_3, K_4)}{R_2}, \cdots, \frac{a^{R_5}(K_1, K_2, K_3, K_4)}{R_5,}\}$$

The aggregation is graphically presented in Figure 5.
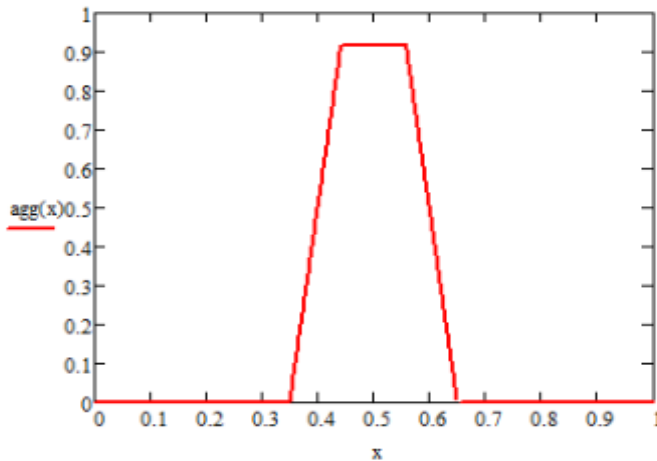
Figure 5. Graphical representation of the aggregation procedure

Defuzzification of the fuzzy set is performed by the method of center of gravity according to the formula:

$$S = \frac{\int_0^1 x \cdot agg(x)dx}{\int_0^1 agg(x)dx}$$

– at the final stage, the procedure of fuzzification of the obtained quantitative characteristic is carried out in order to obtain the most understandable and corresponding to the primary logic of judgments assessment, which will also allow for a graphic interpretation of the level of stability of the self-employed market (Figure 6).

$\alpha_1(S) = 0$ $\alpha_2(S) = 0$ $\alpha_3(S) = 1$ $\alpha_4(S) = 0$ $\alpha_5(S) = 0$
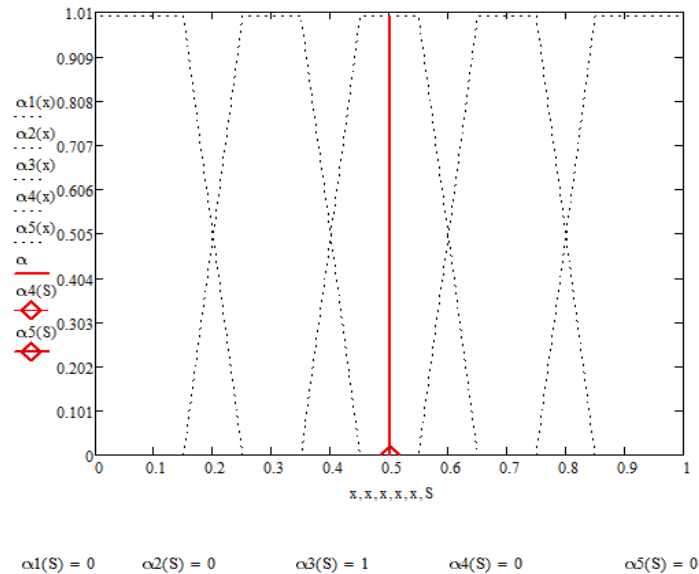
Figure 6. Graphical representation of the level of stability of the self-employed market of the Russian Federation in 2021.

The results of the calculations are presented in Table 4.

Table 4
Representation of stability via the characteristics of functioning

	Characteristics	Ki	Intermediate characteristics	Zi	Indicators	xi	Assessment
Stability	Reliability	K_1 0.5	Labor market	Z_1 0.489	Unemployment rate	X_1	0.39
					Difference between the average per capita income of the self-employed and hired workers	X_2	0.45
					The presence of the main place of employment	X_3	0.37
			Investment climate	Z_2 0.415	Consumer price level	X_4	0.33
					Access to borrowed funds	X_5	0.32
					Availability of state programs	X_6	0.63
			Organizational and legal basis	Z_3 0.5	Equality of interaction with natural persons and legal entities	X_7	0.56
					Ease of registration and reporting	X_8	0.62
	Market value	K_2 0.5			Competition level	X_9	0.50
					Market development prospects	X_{10}	0.63
	Potential	K_3 0.5	Entrepreneurial activity	Z_4 0.5	Ability to see a business opportunity and formulate a business idea	X_{11}	0.78
					Financial literacy	X_{12}	0.50

				Ability to recognize and assess economic trends, market trends, and market deficits	X_{13}	0.58
				Population's attitude to risk	X_{14}	0.67
		Resource availability	Z_5 0.263	Dependence on fixed assets	X_{15}	0.24
				Starting capital	X_{16}	0.42
				Level of digitalization	X_{17}	0.63
Efficiency	K_4 0.617	Deductions	Z_6 0.695	Contributions to pension and social insurance	X_{18}	0.74
				Tax deductions	X_{19}	0.80
		Business metrics	Z_7 0.5	The number of checks generated by self-employed people	X_{20}	0.49
				The number of registered self-employed people	X_{21}	0.37
				The volume of tax revenues from the self-employed	X_{22}	0.54

Source: Compiled by the authors

The results of the calculations presented above suggest that the level of stability of the Russian self-employed market equals 0.5, which corresponds to the third level of the five-level classification. This set is characterized by the following linguistic definition – the functioning of the market is stable and its characteristic corresponds to the level of "satisfactory (average)". This suggests that the self-employed market in the Russian Federation has a fairly good potential for growth, as there are no signs of its slowdown. The last 4 years show good preconditions for the transition to a qualitatively better status of the market infrastructure.

It is important to note that the result of the assessment is both the initial variable, which is an integral indicator of the stability of market functioning, and the output variables by levels of the hierarchy. For example, on the third level of the hierarchy, we get the results for four characteristics: reliability, market value, potential, and efficiency, which, in turn, are the input variables for determining the integral indicator. Notably, three characteristics demonstrate the average level of the indicator, and the effectiveness according to the results of the study is equal to 0.617. This value of the indicator demonstrates the presence of potential, which confirms the need for further research and development of the self-employed market.

4. CONCLUSIONS

The results obtained can be used both by professional participants and external users at the level of ministries, committees, regulatory organizations, etc. for the purposes of adjusting policies and strategies and choosing justified tactical measures to regulate the labor market

and self-employment market in particular. Internal use of the assessment results makes it possible to identify the factors that cause uncontrolled fluctuations in the stability of functioning of the self-employed market.

These directions for the development of the self-employed market will enable the improvement of the indicators of characteristics in the structure of the integral market stability indicator. Repeated application of the proposed assessment algorithm and the formed results of the assessment of market functioning stability determine how much the input variables have changed under the influence of external environment factors and how it is reflected in the characteristics of the integral indicator of functioning stability.

The results of the assessment provide the basis for activating ways to ensure or maintain the stability of market functioning and enable a rapid real-time response to deviations of input variables, intermediate indicators, characteristics, as well as the integral indicator of the sustainability of the self-employed market itself.

5. IMITATIONS

The self-employed can belong to different industries, and the study did not make adjustments for the industry and the extent to which information technology is used in self-employment. Furthermore, the experts each represent their own cluster, and the teachers may focus more on strengthening the indicators other than those emphasized by the self-employed.

Next, we shall discuss the groups of factors not included in the survey for our study.

At first, there was an initiative to add the factor "population income", but this factor is difficult to take into consideration without knowing price levels or purchasing power. Therefore, this factor was excluded from the survey at the stage of its validation.

Instead, we deemed it necessary to add the factor "Difference between the average per capita income of the self-employed and hired workers" due to the assumption that hired workers have no reason to become self-employed if their income is equal to or greater than that of the self-employed. This factor leaves out the socio-psychological aspects and considers only the economic ones. On the other hand, in developing countries with high unemployment rates, being self-employed is a way out of poverty or a way to cover primary needs.

The variable "exchange rate of the national currency against other currencies" was also excluded from the survey, because although this variable belongs to the "investment climate" group, it refers more to the corporate sector of the economy. Thus, it was decided to remove this variable. Another variable we ruled out was the "hereditary variable," according to which self-employment activity is hereditary and is most prevalent in those whose parents were self-employed. Moreover, the importance of this factor can vary from country to country in view of specific legal conditions and entrepreneurial culture. The study has no correction for the industry, so its results cannot be extrapolated. However, the main reason behind this failure is not really the potential for extrapolation, but the fact that Russian entrepreneurship is about 30 years old and, accordingly, has not yet had time for the generation of entrepreneurs to change.

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Appendix 1.

Expert	x1	x2	x3	x4	x5	x6	x7	x8	x9	x10	x11	
1	0.5	0.6	0.1	0.4	0.7	0.8	0.7	0.8	0.7	0.7	0.9	Teacher
2	0.7	0.4	0.2	0.3	0.8	0.8	0.6	0.5	0.5	0.6	0.8	Teacher
3	0.5	0.5	0.2	0.6	0.6	0.7	0.5	0.6	0.5	0.8	0.9	Teacher
4	0.4	0.5	0.3	0.5	0.2	0.5	0.8	0.4	0.6	0.6	0.8	Teacher
5	0.2	0.1	0.3	0.2	0.1	0.5	0.8	0.4	0.3	0.6	0.8	Self-employed
6	0.3	0.4	0.4	0.3	0.3	0.3	0.6	0.9	0.7	0.4	0.9	Self-employed
7	0.2	0.2	0.2	0.6	0.2	0.3	0.5	0.6	0.5	0.6	0.6	Self-employed
8	0.3	0.3	0.5	0.4	0.2	0.4	0.6	0.4	0.7	0.7	0.8	Self-employed
9	0.6	0.7	0.4	0.2	0.2	0.8	0.4	0.8	0.3	0.7	0.7	Self-employment specialist
10	0.4	0.8	0.7	0.1	0.1	0.9	0.3	0.7	0.2	0.6	0.8	Self-employment specialist
11	0.3	0.5	0.5	0.1	0.2	0.7	0.5	0.8	0.6	0.8	0.6	Self-employment specialist
12	0.3	0.4	0.6	0.2	0.2	0.8	0.4	0.5	0.4	0.5	0.7	Self-employment specialist
Expert	x12	x13	x14	x15	x16	x17	x18	x19	x20	x21	x22	
1	0.6	0.8	0.9	0.3	0.3	0.5	0.6	0.6	0.7	0.5	0.7	Teacher
2	0.4	0.7	0.8	0.2	0.5	0.6	0.7	0.7	0.6	0.6	0.6	Teacher
3	0.5	0.7	0.9	0.2	0.4	0.7	0.7	0.7	0.6	0.4	0.5	Teacher

4	0.3	0.5	0.6	0.2	0.4	0.5	0.6	0.6	0.5	0.3	0.7	Teacher
5	0.2	0.6	0.5	0.2	0.3	0.9	0.9	0.9	0.2	0.1	0.2	Self-employed
6	0.4	0.6	0.7	0.6	0.2	0.7	0.7	0.9	0.3	0.1	0.3	Self-employed
7	0.3	0.5	0.6	0.3	0.6	0.6	0.6	0.9	0.1	0.3	0.2	Self-employed
8	0.6	0.4	0.4	0.1	0.4	0.9	0.7	0.9	0.1	0.3	0.4	Self-employed
9	0.7	0.6	0.8	0.1	0.7	0.6	0.9	0.9	0.6	0.6	0.8	Self-employment specialist
10	0.6	0.3	0.7	0.2	0.5	0.7	0.7	0.7	0.7	0.5	0.7	Self-employment specialist
11	0.8	0.5	0.4	0.3	0.4	0.5	0.9	0.9	0.7	0.4	0.8	Self-employment specialist
12	0.6	0.7	0.7	0.2	0.3	0.4	0.9	0.9	0.8	0.3	0.6	Self-employment specialist