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### FORMATION OF A SYSTEM OF INDICATORS AND MODELING OF ACTIVATION OF INNOVATIVE ACTIVITY OF SMALL AND MEDIUM ENTERPRISES

**Abstract.** The article considers the topical issue of intensifying the innovative activity of small and medium enterprises. In the course of the research, the structure of innovative activity of the enterprise was allocated to the subsystems: «Innovative activity», «Production and economic activity» and «State support and financial support». Scientific economic and mathematical methods such as a priori ranking, linguistic analysis, and cognitive modeling are used to identify and graphically represent the cause-and-effect relationships of the system. The a priori ranking allowed identifying indicators that from the point of view of scientists should be used in the analysis of subsystems. As a result, the causal links between the performance subsystems of small and medium-sized enterprises are identified and the indicators that have the greatest impact are identified. According to the simulation results, in order to intensify the innovation activity of small and medium enterprises, it is necessary to focus on the efficiency of the existing infrastructure of small and medium enterprises support, study the supply and demand in the market of business development services which will ensure compliance of services in the field of services for business development with the actual needs of small and medium enterprises. On the basis of the analysis of the received ratios of consonance, negative and positive influence it is possible to choose an acceptable strategy, for will promote increase of activation of innovative processes of small and average enterprises.

**Keywords:** innovation activity, production and economic activity, small and medium enterprises, SME support, business development.

**JEL Classification** O30, O31, O38

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### ФОРМУВАННЯ СИСТЕМИ ПОКАЗНИКІВ ТА МОДЕЛЮВАННЯ АКТИВІЗАЦІЇ ІННОВАЦІЙНОЇ ДІЯЛЬНОСТІ МАЛИХ І СЕРЕДНІХ ПІДПРИЄМСТВ

**Анотація.** Розглядається актуальне питання активізації інноваційної діяльності малих і середніх підприємств. У ході дослідження було виділено структуру інноваційної діяльності підприємства на підсистеми: «Інноваційна активність», «Виробничо-господарська діяльність» і «Державна підтримка та фінансове забезпечення». Використано такі наукові економічно-математичні методи, як апіорне ранжування, лінгвістичний аналіз та когнітивне

моделювання для виявлення і графічного зображення причинно-наслідкових зв'язків відповідної системи. Проведено апріорне ранжування дозволило виділити показники, які з позицій науковців доцільно використовувати у процесі аналізу підсистем. У результаті визначено причинно-наслідкові зв'язки між показниками підсистем інноваційної діяльності малих і середніх підприємств та відокремлено показники, які справляють найбільший вплив. Відповідно до результатів моделювання для активізації інноваційної діяльності малих і середніх підприємств варто зосередити увагу на ефективності наявної інфраструктури підтримки малих та середніх підприємств, вивчити попит і пропозицію на ринку послуг для розвитку бізнесу, що дозволить забезпечити відповідність послуг у сфері послуг для розвитку бізнесу фактичним потребам малих і середніх підприємств. На основі аналізу отриманих співвідношень консонансу, негативного і позитивного впливу можна обрати прийнятну стратегію, що сприятиме підвищенню активізації інноваційних процесів малих і середніх підприємств.

**Ключові слова:** інноваційна діяльність, виробничо-господарська діяльність, малі та середні підприємства, підтримка МСП, розвиток бізнесу.

Формул: 0; рис.: 4; табл.: 6; бібл.: 17.

**Introduction.** To ensure the development of innovation activities of small and medium enterprises, it is important to develop new methods of forming and activating elements of the innovation system, which must meet the objectives of socio-economic trends, as well as direct their action to overcome disparities in innovation development. This applies to the promotion of access to resource markets (including financial), improving infrastructure, organizational and methodological support, and training of entrepreneurs.

Modern innovation trends significantly affect business processes as a basis for the formation of market relations. The multi-vector nature of innovation creates a diversity of public policy in the new socio-economic environment, focused on stimulating small and medium enterprises and infrastructure support, networking, assistance in innovation, science, and industry, and more.

The development of areas of innovation system management and management decisions involves determining the relationship of quantitative and qualitative components, which should be based on the use of economic and mathematical modeling, which allows linking the current state of objects and scenarios with future states of the system.

**Literature review and problem statement.** The works of such scientists as Z. Lytvyn [1], A. Kasych and K. Kanunikova [2], N. Lepetyukha [3], O. Cheresnyuk [4], P. Kurmaev [5], Yu. Nikitin [6], A. Stelmashchuk [7], A. Shevchenko [8], Yu. Shushkova [9], G. Palchevych [10], S. Kisil [11], I. Hnatenko [12], S. Usherenko [13] are devoted to the assessment of the state and directions of intensification of innovative activity of enterprises. The works of scientists note the importance of innovative development for enterprises and the economy as a whole. However, the issue of forming a system of indicators and modeling the intensification of innovation activities of small and medium enterprises remains insufficiently developed.

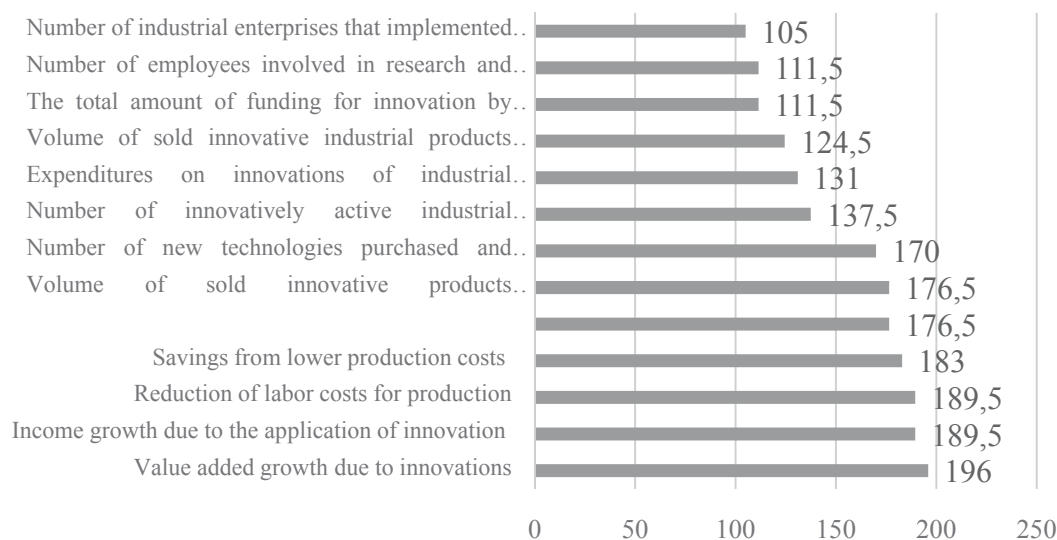
The aim of the article is to form a system of indicators and model the activation of innovation of small and medium enterprises, which in turn allow to determine the causal links between indicators of subsystems of innovation of small and medium enterprises and to identify indicators that have the greatest impact.

**Methodology.** The research uses such scientific economic and mathematical methods as a priori ranking, linguistic analysis, and cognitive modeling to identify and graphically represent the cause-and-effect relationships of the system.

**Results.** For the analysis, we propose to allocate the structure of innovative activity of the enterprise on the following subsystems: «Innovative activity», «Production and economic activity» and «State support and financial support». Therefore, further research is aimed at forming indicators and determining their relationships and concepts of impact. This will allow, firstly, identifying weaknesses in the process of innovation of SMEs and developing measures to improve their status, and, secondly, to identify the most promising indicators, taking into account the specifics of innovation.

The implementation of successive stages must be carried out separately for each of the elements of the structure of innovation activities of SMEs, i.e. will include the formation of indicators for the subsystems «Innovation Activity», «Production and Economic Activity» and «Government Support and Financial Support».

The conducted a priori ranking allowed to allocate indicators which from the point of view of scientists [14, 15] expedient to use in the process of analysis of the subsystem «Innovation activity» innovative activity of small and medium enterprises (innovation activity of SMEs) (Fig. 1).



**Fig. 1. Rank values of indicators reflecting the subsystem «Innovation activity» of innovation activity of SMEs, obtained using the a priori ranking algorithm**

Source: compiled by the authors based on [16].

The partial degree of agreement in the authors’ opinions on the evaluation of the subsystem «Innovation Activity» of the SME innovation activity is confirmed by the value of the concordance coefficient ( $\omega = 0,445$ ): this value is statistically significant when tested by Pearson’s criterion ( $\chi^2_p = 133 > \chi^2_\tau = 40,3$ ).

The analysis showed that out of the total data set (13 indicators) eight indicators have the greatest significance and influence in assessing the level of innovative activity of SMEs and therefore can be used in further calculations. Value-added growth due to innovations was excluded from the general system of indicators; income growth due to the application of innovation; savings from reducing the cost of production; reduction of labor costs for production; the volume of sold innovative products (goods, services) and adjust the selected system of indicators (Table 1).

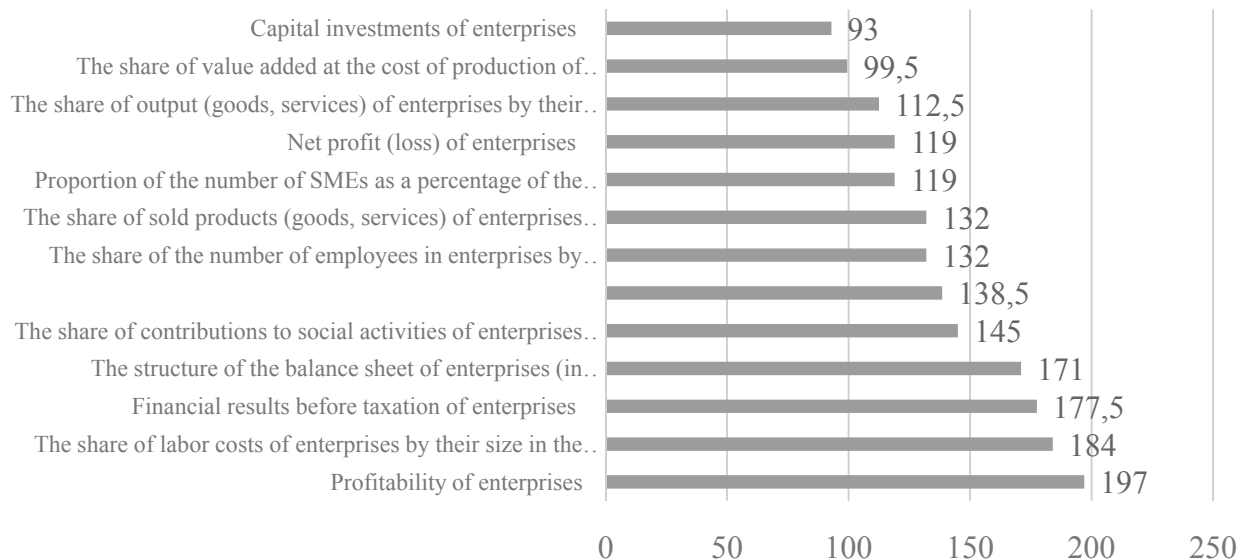
Table 1

**System of indicators that characterizes the subsystem «Innovation activity» of innovation activities of SMEs**

Indicator	Symbol	Unit of measurement
Number of innovatively active enterprises % to the total number of enterprises	IA <sub>1</sub>	%
Expenditures on innovations of enterprises % to the total volume of sold innovative products (goods, services)	IA <sub>2</sub>	%
The total amount of funding for innovation by source	IA <sub>3</sub>	uah
Number of enterprises that implemented innovations (products and / or technological processes) % of the total number of enterprises	IA <sub>4</sub>	%
The number of introduced innovative products (goods, services) by enterprises	IA <sub>5</sub>	units
Number of new technologies purchased and transferred by enterprises	IA <sub>6</sub>	units
Number of employees involved in research and development	IA <sub>7</sub>	persons
Volume of sold innovative industrial products (goods, services) % to the total volume of sold industrial products (goods, services)	IA <sub>8</sub>	%

Source: authors’ development.

The formation of the statistical base for the analysis of «Production and economic activity» of the SME is carried out on the basis of research and selection of indicators characterizing the level of functioning of enterprises, and data processing is carried out using an a priori ranking algorithm [17, p. 97—98]. The analysis showed that of the total data set (13 indicators) the first 9 indicators have the greatest significance and influence in assessing the effectiveness of SMEs, and therefore can be used in further calculations (Fig. 2). All these indicators were included in further research. The partial degree of agreement of the authors’ opinions on the evaluation of the efficiency of the enterprise is confirmed by the value of the concordance coefficient ( $\omega = 37,5$ ): this value is statistically significant when tested by Pearson’s test ( $\chi^2_p = 9924,8 > \chi^2_{\tau} = 37,57$ ).



**Fig. 2. Ranking values of indicators characterizing the subsystem «Production and economic activity» of innovation activity of SMEs, obtained using the algorithm of a priori ranking**

Source: compiled by the authors based on [16].

Verification of the statistical significance of the previously proposed system of partial indicators of the subsystem «Production and economic activity» of the SME innovation activity allowed to adjust the selected system of indicators, which were combined into a group (Table 2).

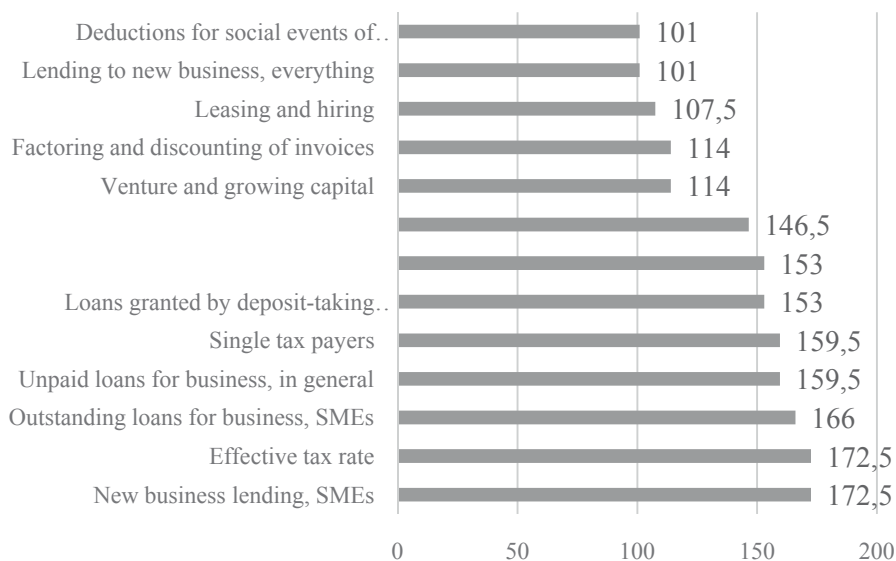
Table 2

**System of indicators that characterizes the subsystem «Production and economic activity» of innovation activity of SMEs**

Indicator	Symbol	Unit of measurement
Proportion of the number of SMEs as a percentage of the total number of entities	PEA <sub>1</sub>	%
Share of employees in business entities by their size in the total number of employees in business entities	PEA <sub>2</sub>	%
The share of personnel costs of economic entities by their size in the total personnel costs of economic entities	PEA <sub>3</sub>	%
The share of contributions to social activities of economic entities by their size in the total contributions to social activities of economic entities	PEA <sub>4</sub>	%
The share of sales of entities management by their size in the total volume of sold products (goods, services) of business entities	PEA <sub>5</sub>	%
The share of the volume of products (goods, services) of entities management by their size in the total volume of products (goods, services) of economic entities	PEA <sub>6</sub>	%
The share of value added by the cost of production of entities management by their size in total value added production costs of economic entities	PEA <sub>7</sub>	%
Capital investments of enterprises	PEA <sub>8</sub>	uah
Net profit (loss) of enterprises	PEA <sub>9</sub>	uah

Source: authors’ development.

To form a system of indicators of the subsystem «State support and financial support» of innovation activities of SMEs, similarly to the previous stages, we use the data published in the literature [16], we use the mechanism of a priori ranking to formalize a priori information about the object of study. An additional chart of ranks for the analyzed evaluation indicators of the subsystem «State support and financial support» of innovation activity of SMEs is presented in Fig. 3.



**Fig. 3. Ranking values of indicators characterizing the subsystem «State support and financial support» of innovation activities of SMEs, obtained using the algorithm of a priori ranking**

Source: compiled by the authors based on [16].

According to the results of calculations from the given data set (13 indicators) in the further research 5 of them will be used. Those that are least significant and have little effect on the evaluation results are excluded from further study.

All other indicators were included in the subsequent study. The partial degree of agreement of the authors' opinions on the evaluation indicators is confirmed by the value of the concordance coefficient ( $\omega = 0,37$ ): this value is statistically significant when tested by Pearson's test ( $\chi^2_p = 100,66 > \chi^2_\tau = 37,57$ ). From the selected indicators the system of indicators of the level of the state support and financial maintenance in the innovative activity of SME is formed (Table 3).

Table 3

**System of indicators that characterizes the subsystem «State support and financial support» of innovation activities of SMEs**

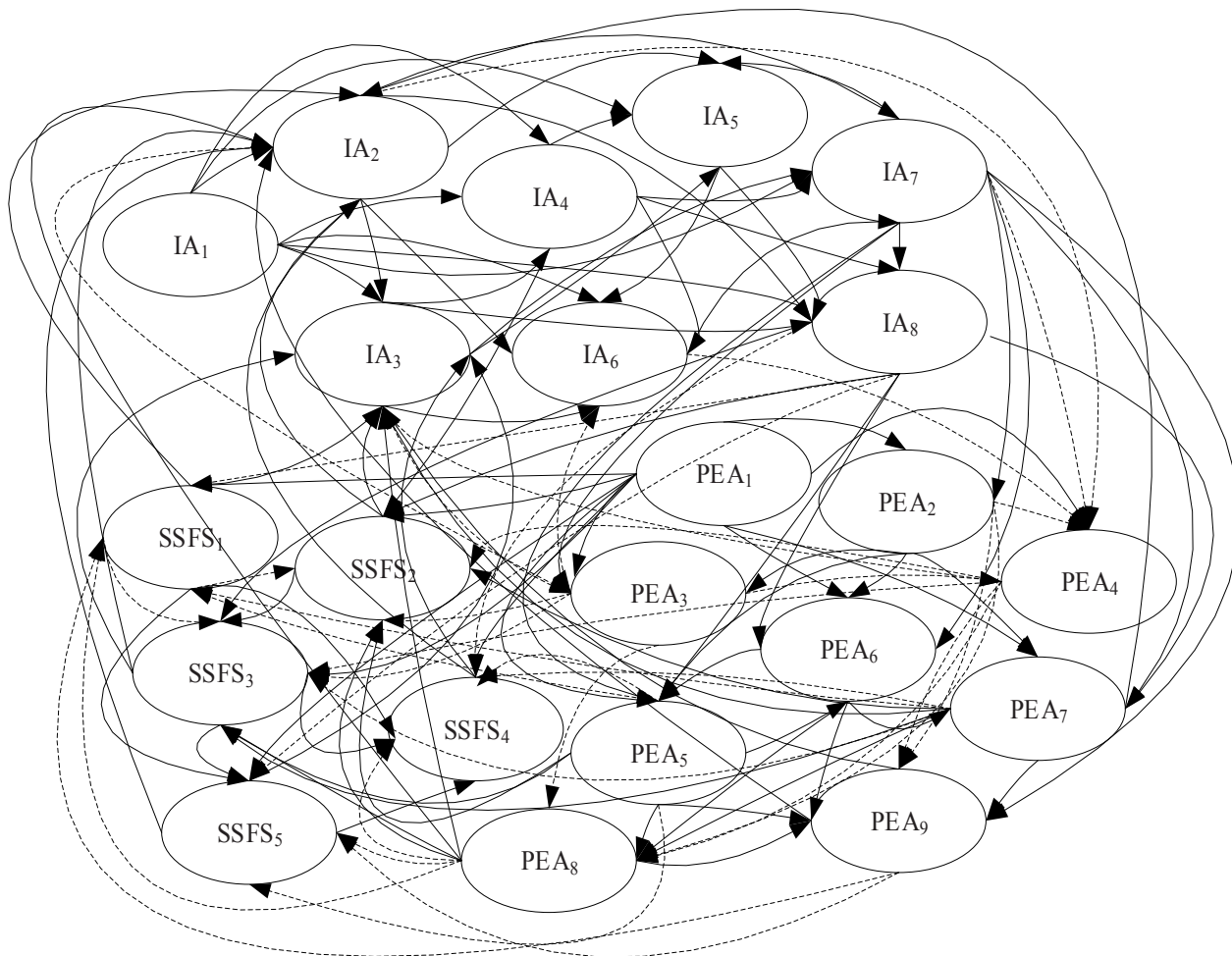
Indicator	Symbol	Unit of measurement
Lending to new business	SSFS <sub>1</sub>	uah
Venture and growing capital	SSFS <sub>2</sub>	uah
Leasing and hiring	SSFS <sub>3</sub>	uah
Factoring and discounting of invoices	SSFS <sub>4</sub>	uah
Deductions for social events of enterprises according to their size	SSFS <sub>5</sub>	uah

Source: authors' development.

To build a cognitive map as concepts (factors) used a selected system of indicators for evaluating the innovation performance of SMEs by subsystems. To determine the relationship of causality and the direction of influence between the selected indicators, a matrix is constructed (Table 4). The direction of influence (direct and reverse), the reflection of the relationship «cause — effect» between indicators.



Based on the analysis of system indicators and  $\alpha$ -sections the concepts, and also degree and reliability of their influence are allocated. This information is used to generate alternatives, which are then tested using dynamic modeling based on the method of pulse processes (Fig. 4).



**Fig. 4. A symbolic digraph of the cognitive map of the impact of causal links on the intensification of innovation activities of SMEs**

Source: authors' development.

Table 4

Cognitive matrix of cause-and-effect relations of activation of innovation activity of SMEs

	IA <sub>1</sub>	IA <sub>2</sub>	IA <sub>3</sub>	IA <sub>4</sub>	IA <sub>5</sub>	IA <sub>6</sub>	IA <sub>7</sub>	IA <sub>8</sub>	PEA <sub>1</sub>	PEA <sub>2</sub>	PEA <sub>3</sub>	PEA <sub>4</sub>	PEA <sub>5</sub>	PEA <sub>6</sub>	PEA <sub>7</sub>	PEA <sub>8</sub>	PEA <sub>9</sub>	SSFS <sub>1</sub>	SSFS <sub>2</sub>	SSFS <sub>3</sub>	SSFS <sub>4</sub>	SSFS <sub>5</sub>	
IA <sub>1</sub>	0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
IA <sub>2</sub>	+	0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
IA <sub>3</sub>	+	+	0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
IA <sub>4</sub>	+	+	+	0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
IA <sub>5</sub>	+	+	+	+	0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
IA <sub>6</sub>	+	+	+	+	+	0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
IA <sub>7</sub>	+	+	+	+	+	+	0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
IA <sub>8</sub>	+	+	+	+	+	+	+	0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
PEA <sub>1</sub>	0	0	0	0	0	0	0	0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
PEA <sub>2</sub>	0	0	0	0	0	0	0	0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
PEA <sub>3</sub>	0	0	0	0	0	0	0	0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
PEA <sub>4</sub>	0	0	0	0	0	0	0	0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
PEA <sub>5</sub>	0	0	0	0	0	0	0	0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
PEA <sub>6</sub>	0	0	0	0	0	0	0	0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
PEA <sub>7</sub>	0	0	0	0	0	0	0	0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
PEA <sub>8</sub>	0	0	0	0	0	0	0	0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
PEA <sub>9</sub>	0	0	0	0	0	0	0	0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
SSFS <sub>1</sub>	0	0	0	0	0	0	0	0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
SSFS <sub>2</sub>	0	0	0	0	0	0	0	0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
SSFS <sub>3</sub>	0	0	0	0	0	0	0	0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
SSFS <sub>4</sub>	0	0	0	0	0	0	0	0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
SSFS <sub>5</sub>	0	0	0	0	0	0	0	0	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

Source: authors' development.

In addition to quantitative calculations, we consider it expedient to provide their qualitative estimates in accordance with the introduced linguistic sets (*Tables 5, 6*).

Table 5

**Assessment of systemic characteristics of the cognitive model while supporting the identification of causal links to innovation activities of SMEs**

Indicator	Consonance of the system's influence on the indicator	Dissonance of the system's influence on the indicator	Consonance of the impact of the indicator on the system	Dissonance of the impact of the indicator on the system
IA <sub>1</sub>	1	0	1	0
IA <sub>2</sub>	0,46	0,54	0,91	0,09
IA <sub>3</sub>	0,46	0,54	0,92	0,08
IA <sub>4</sub>	1	0	1	0
IA <sub>5</sub>	1	0	1	0
IA <sub>6</sub>	0,65	0,35	0,86	0,15
IA <sub>7</sub>	0,87	0,13	0,95	0,07
IA <sub>8</sub>	0,72	0,28	0,71	0,27
PEA <sub>1</sub>	1	0	1	0
PEA <sub>2</sub>	0,61	0,39	0,61	0,41
PEA <sub>3</sub>	0,49	0,51	0,58	0,43
PEA <sub>4</sub>	0,49	0,51	0,48	0,54
PEA <sub>5</sub>	0,7	0,3	0,63	0,34
PEA <sub>6</sub>	0,73	0,27	0,62	0,35
PEA <sub>7</sub>	0,75	0,25	0,64	0,33
PEA <sub>8</sub>	0,52	0,48	0,48	0,5
PEA <sub>9</sub>	0,58	0,42	0,52	0,46
SSFS <sub>1</sub>	0,54	0,46	0,48	0,54
SSFS <sub>2</sub>	0,63	0,37	0,62	0,36
SSFS <sub>3</sub>	0,68	0,32	0,62	0,36
SSFS <sub>4</sub>	0,57	0,43	0,49	0,52
SSFS <sub>5</sub>	0,58	0,42	0,52	0,5

Table 6

**Scales and criteria for systemic characteristics of the cognitive model for identifying the cause-and-effect relationships of SME innovation**

Designation of the integrated indicator	Criteria for systemic characteristics of the cognitive model for identifying the causal links of the intensification of innovation activity of SMEs		
	H	C	B
Consonance of the system's influence on the indicator	[0,46;0,64)	[0,64;0,82)	[0,82;1]
Dissonance of the system's influence on the indicator	[0;0,18)	[0,18;0,3)	[0,36;0,54]
Consonance of the impact of the indicator on the system	[0,45;0,63)	[0,63;0,8)	[0,8;1]
Dissonance of the impact of the indicator on the system	[0;18)	[0,18;0,37)	[0,37;0,56]

The system has a high level of positive impact on such indicators as the number of innovative enterprises (1), the number of enterprises that implemented innovations (products and/or technological processes) (1), the number of introduced innovative products (1), the number of employees involved in research and development (0.87), the number of SMEs (1).

The system has a high level of negative impact on such indicators as the cost of innovation of industrial enterprises (0.54), the total funding of innovation (0.54), the share of employees (0.39), the share of personnel costs (0.51), the share of contributions to social activities (0.51), capital investment (0.48), net profit (loss) of enterprises and profitability of enterprises (0.42), new lending



to SMEs (0.46), venture and growth capital (0.37), factoring and discounting of invoices (0.43), loans granted by deposit-taking corporations to non-financial corporations (0.42).

The high level of positive impact on the system is exerted by such indicators as the number of innovatively active industrial enterprises (1), the cost of innovation of industrial enterprises (0.91), the total funding of innovation (0.92), the number of industrial enterprises that implemented innovations products and/or technological processes (1), the number of introduced innovative products (goods, services) by industrial enterprises (1), the number of purchased and transferred new technologies by industrial enterprises (0.86), the number of employees involved in research and development (0.95), the share of the number of SMEs as a percentage of the total number of entities (1).

The high level of negative impact on the system is exerted by the share of the number of employees (0.41), the share of personnel and wage costs (0.43), the share of contributions to social activities (0.54), capital investments (0.5), net profit (loss) of enterprises (0.46), new lending to SMEs (0.54), factoring and discounting of invoices (0.52), loans granted by deposit-taking corporations to non-financial corporations (0.5).

**Conclusions.** Therefore, in order to intensify the innovation activity of SMEs and to improve the conditions for innovation activity of SMEs, the government should focus on stimulating the involvement of SMEs in the processes of forming innovation ecosystems and providing them with information-analytical, advisory and organizational support.

Analysis of the dissonance of the system's impact on indicators necessitates the development of mechanisms for financial stimulation of SME innovation (introduction of a system of tax benefits and tax holidays in the first years of operation; creation of a subsidy system; providing foreign investors with favorable conditions state support, etc.).

According to the simulation results, in order to intensify SME innovation, it is necessary to focus on the effectiveness of the existing SME support infrastructure, study the supply and demand in the business services market, which will ensure compliance of business services with the actual needs of SMEs.

Lack of motivation for radical reform requires the development of mechanisms to financially support the implementation of innovation activities of SMEs, which will include credit and investment components and allow distributing risks among participants in innovation projects through venture investment programs; state credit guarantees; tax incentives, etc.

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