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MODELING THE INNOVATIVE DEVELOPMENT OF BUSINESS STRUCTURES IN THE CONDITIONS OF POST-WAR ECONOMIC RECOVERY

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INTRODUCTION. Modeling the innovative development of business structures in the conditions of post-war economic recovery is the process of developing and applying economic, mathematical, organizational and digital models to substantiate management decisions regarding the recovery, modernization and sustainable development of enterprises after the end of hostilities. The main goal of such modeling is to ensure the rapid adaptation of business to new economic conditions, increase its competitiveness, innovative activity and resilience to future crises.

In the conditions of post-war recovery, the innovative development of business structures acquires particular importance, since the recovery of the economy requires not only the reconstruction of production facilities, but also the transition to innovation, digital transformation, development of human capital and integration into international production and logistics chains. These aspects reflect the importance of the innovative development of business structures in the conditions of post-war economic recovery of the state.

THE HYPOTHESIS OF THE SCIENTIFIC RESEARCH is to study the process of innovative development of business structures, namely the use of multidimensional comparative analysis, which allows taking into account not only the absolute values of business structure indicators, but also the degree of their proximity (distance) to the benchmark indicators.

THE PURPOSE OF THE RESEARCH: to assess the innovative potential; to identify factors that influence innovative development; to predict the results of the implementation of innovations.

THE RESEARCH METHODOLOGY is based on the use of scientific methods of econometric modeling to predict innovative activity; system dynamics to analyze the relationships between development factors; cluster modeling to study various development scenarios.

CONCLUSIONS AND PROSPECTS FOR FURTHER RESEARCH. Modeling the innovative development of business structures is the process of creating and using models to analyze, predict and manage the implementation of innovations in the activities of business structures in order to increase their competitiveness and long-term development.

KEYWORDS: business structures; innovation efficiency; innovation process; clustering; modeling.

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
12	7	3

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МОДЕЛЮВАННЯ ІННОВАЦІЙНОГО РОЗВИТКУ БІЗНЕС-СТРУКТУР В УМОВАХ ПІСЛЯВОЄННОГО ВІДНОВЛЕННЯ ЕКОНОМІКИ

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ВСТУП. Моделювання інноваційного розвитку бізнес-структур в умовах повоєнного відновлення – це процес розроблення та застосування економічних, математичних, організаційних і цифрових моделей для обґрунтування управлінських рішень щодо відновлення, модернізації та сталого розвитку підприємств після завершення воєнних дій. Основною метою такого моделювання є забезпечення швидкої адаптації бізнесу до нових економічних умов, підвищення його конкурентоспроможності, інноваційної активності та стійкості до майбутніх криз.

В умовах повоєнного відновлення інноваційний розвиток бізнес-структур набуває особливого значення, оскільки відновлення економіки потребує не лише реконструкції виробничих потужностей, а й переходу до сучасних технологій, цифрової трансформації, розвитку людського капіталу та інтеграції у міжнародні виробничі й логістичні ланцюги. Ці аспекти відображають важливість інноваційного розвитку бізнес-структур в умовах післявоєнного відновлення економіки держави.

ГІПОТЕЗА НАУКОВОГО ДОСЛІДЖЕННЯ полягає в дослідженні процесу інноваційного розвитку бізнес-структур, а саме використання багатовимірного порівняльного аналізу, який враховує не тільки абсолютні величини показників бізнес-структур, але і ступінь їхньої близькості (дальності) до показників еталона.

МЕТА ДОСЛІДЖЕННЯ: оцінити інноваційний потенціал; визначити фактори, що впливають на інноваційний розвиток; спрогнозувати результати впровадження інновацій.

МЕТОДОЛОГІЯ ДОСЛІДЖЕННЯ базується на використанні наукових методів економетричного моделювання для прогнозування інноваційної активності; системної динаміки для аналізу взаємозв'язків між факторами розвитку; кластерне моделювання для дослідження різних сценаріїв розвитку.

ВИСНОВКИ ТА ПЕРСПЕКТИВИ ПОДАЛЬШИХ ДОСЛІДЖЕНЬ. Моделювання інноваційного розвитку бізнес-структур – це процес створення та використання моделей для аналізу, прогнозування та управління впровадженням інновацій у діяльності бізнес-структур з метою підвищення їхньої конкурентоспроможності та довгострокового розвитку.

КЛЮЧОВІ СЛОВА: бізнес-структури; ефективність інновації; інноваційний процес; кластеризація; моделювання.

Problem statement. In modeling the innovative development of business structures, it is necessary to consider this process as the basis for technology transfer and the environment of merged enterprises, thanks to which it becomes possible to adapt merged enterprises to external changes.

Modeling stages:

- Setting the goal and defining the problem.
- Selecting factors and indicators.
- Building a simulation model.
- Checking the adequacy of the model.
- Conducting scenario analysis.
- Making management decisions and monitoring results.

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The purpose of the article is to model the innovative development of business structures in the conditions of post-war economic recovery.

Presentation of the main material. The developed model is based on the availability of innovative opportunities in the conditions of post-war economic recovery and the achievement of strategic goals of business structures and their ability to adapt to environmental changes. The relationships between the components of the model are reflected in various forms. Closed innovation models correspond to the positioning of business structures as a violator; for a stakeholder, the use of such a model is complicated due to the fact that its goal is to coordinate innovation processes; for an explent – practically impossible, since such business structures involve licensing innovation objects to third-party enterprises).

The possibility of implementation this proposed model depend on its compliance with internal features – resources, processes and potential of the enterprise: resources; innovative potential.

Based on the analysis of strategic innovative decisions of business structures, it is shown that from the point of view of the relationships and mutual influence of traditional and innovative elements of structures, there are

differences between the types of models for each of the three identified classes of business structures, which is largely determined by the features of innovation, which in turn allows the analyzed entities to take into account and use innovative technologies from know-how markets.

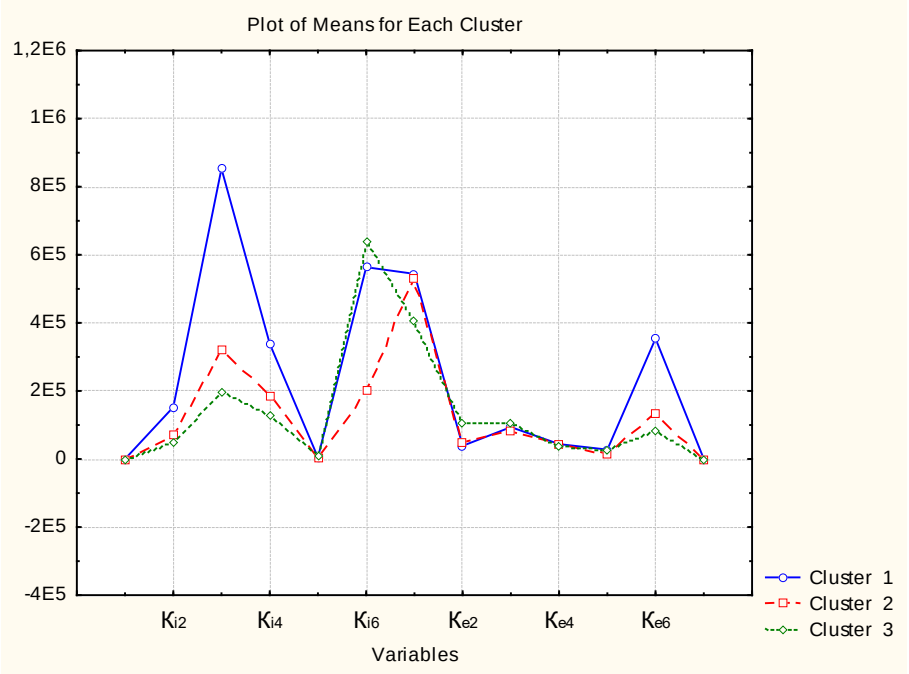
To typify the studied enterprises on the basis of the "Possibility of attracting / providing innovations", their clustering was carried out using the STATISTIKA7 application program package, the list of grouping indicators is given in Table 1.

Table 1

List of indicators for typology of the studied enterprises according to the characteristic "Possibility of attracting/providing innovations"

Introversion of innovation	Innovation extroversion
1. Share of venture capital Ki1 2. Number of acquired innovations (patents, licenses, copyrights, etc.) Ki2 3. Coefficient of expansion of innovative activity Ki3 4. Coefficient of attracted investments in innovative projects Ki4 5. Coefficient of international openness to innovative products Ki5 6. Share of partnership in the activities of the open innovation system Ki6	1. Share of open innovation revenues Ke1 2. Share of open innovation costs Ke2 3. Innovation attrition rate Ke3 4. Outsourcing rate of non-core functions Ke4 5. Knowledge and technology transfer rate Ke5 6. Percentage of information transferred to modern "open innovation" databases Ke6 7. Actual R&D performance Ke7

Source: author's compilation.

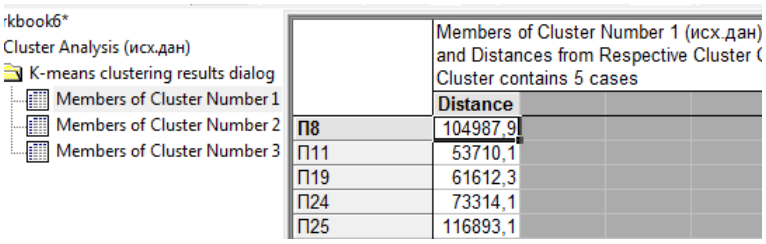


Source: calculated by the author.

Fig. 1. **Listing (fragment of the program) – graphs of average clusters of business structures**

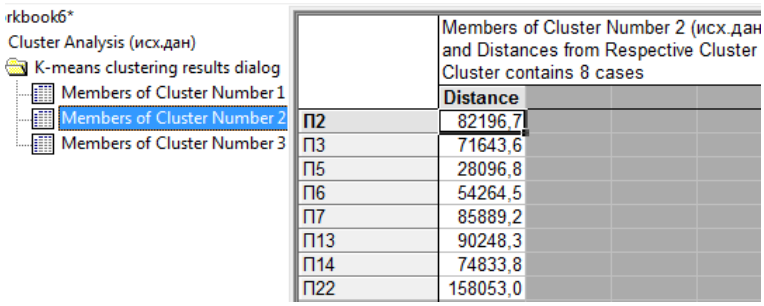
The average graph of each of the obtained clusters is shown in Fig. 1. The cluster analysis and case analysis of typical representatives of the clusters allowed us to confirm the existence of typical variants of the models "Possibility of attracting / providing innovations" and significant relationships between their elements. Multifactor cluster analysis was carried out in order to identify the presence of stable groups of business structures with characteristic relationships between components.

The listing shows that, based on price and technical characteristics, 3 clusters were obtained as a result of the calculations. A description of the clusters obtained as a result of clustering market segments is given in Fig. 2–4.



Source: calculated by the author.

Fig. 2. **Listing (fragment of the program) – business structures included in the 1st cluster**



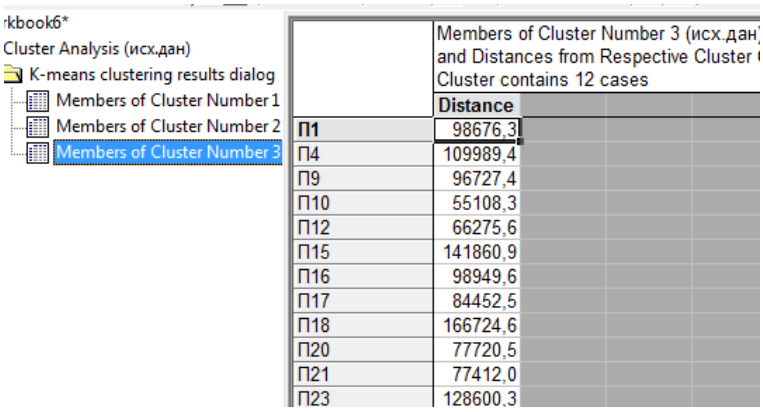
Source: calculated by the author

Fig. 3. **Listing (fragment of the program) – business structures included in the 2nd cluster**

Statistically, the quality of clustering was checked by calculating and evaluating the point-biserial correlation coefficient and C-Index 14, the values of these indices were 0.8 and 0.02, respectively, which indicates a fairly high degree of difference between individual clusters and a high density of observations within clusters.

Based on the results of the classification of business structures, a discriminant model was built to identify their belonging to one of the 3 classes (violents, stakeholders, explents) according to the characteristic "Possibility of attracting/providing innovations". To conduct discriminant analysis, the results of clustering are used, according to which each business structure is assigned the

number of the cluster to which it belongs. Discriminant analysis allows us to recognize new objects, attribute them to existing clusters in order to develop proposals for their corresponding innovative development. The results of the discriminant analysis of the identification of business structures by belonging to one of the three clusters are shown in Fig. 5.

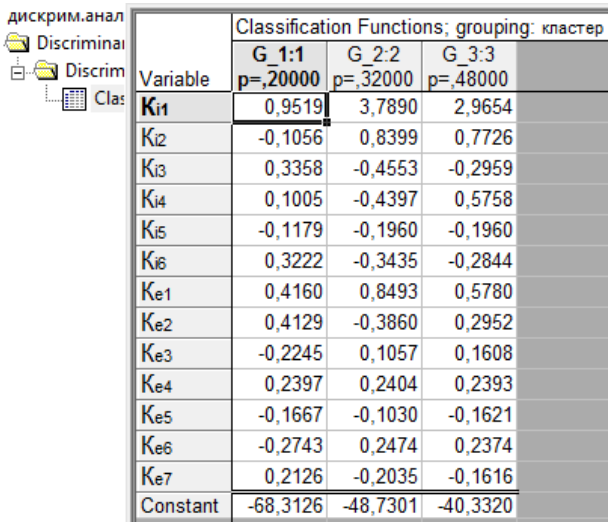

rkbook6*
Cluster Analysis (исх.дан)
K-means clustering results dialog
Members of Cluster Number 1
Members of Cluster Number 2
Members of Cluster Number 3

Members of Cluster Number 3 (исх.дан)
and Distances from Respective Cluster
Cluster contains 12 cases

	Distance
П1	98676,3
П4	109989,4
П9	96727,4
П10	55108,3
П12	66275,6
П15	141860,9
П16	98949,6
П17	84452,5
П18	166724,6
П20	77720,5
П21	77412,0
П23	128600,3

Source: calculated by the author.

Fig. 4. **Listing (fragment of the program) – business structures included in the 1st cluster**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Classification Functions; grouping: кластер

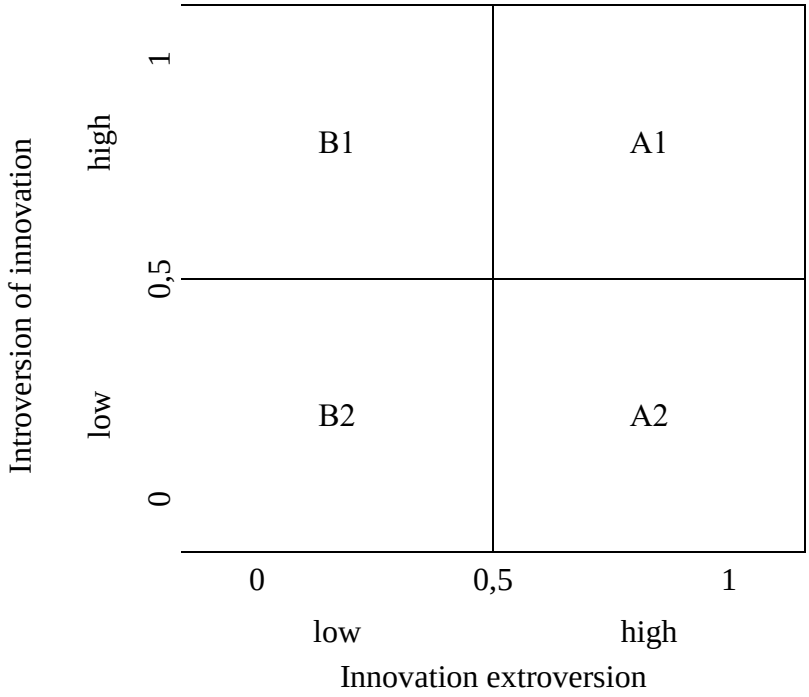
Variable	G_1:1 p=,20000	G_2:2 p=,32000	G_3:3 p=,48000
K_{i1}	0,9519	3,7890	2,9654
K_{i2}	-0,1056	0,8399	0,7726
K_{i3}	0,3358	-0,4553	-0,2959
K_{i4}	0,1005	-0,4397	0,5758
K_{i5}	-0,1179	-0,1960	-0,1960
K_{i6}	0,3222	-0,3435	-0,2844
K_{e1}	0,4160	0,8493	0,5780
K_{e2}	0,4129	-0,3860	0,2952
K_{e3}	-0,2245	0,1057	0,1608
K_{e4}	0,2397	0,2404	0,2393
K_{e5}	-0,1667	-0,1030	-0,1621
K_{e6}	-0,2743	0,2474	0,2374
K_{e7}	0,2126	-0,2035	-0,1616
Constant	-68,3126	-48,7301	-40,3320

Source: calculated by the author.

Fig. 5. **Program listing – results of discriminant analysis of business structures identification by belonging to one of the three clusters**

Information on the distribution of business structures between clusters and the obtained discriminants of the identification model of belonging to one of the 3 classes of violants, stakeholders, explents according to the characteristic "Possibility of attracting / providing innovations".

The next step in building the model is to visualize the obtained results using a two-dimensional matrix. In general, it is presented in Fig. 6.



Source: calculated by the author.

Fig. 6. **Matrix for determining the position of business structures based on the characteristic "Possibility of attracting / providing innovations"**

The positioning of business structures in the proposed matrix along each of the axes (abscissa and ordinate) is proposed to be carried out using the taxonomy method (multidimensional spaces). The taxonomic indicator can take on a value in the interval [0; 1] and has the following interpretation: an individual object in a given period is more developed the closer the value of the generalizing indicator is to unity. It can be used to assess the "average" level of the value of the features characterizing a phenomenon or process achieved in a certain period or moment of time (Porter, 1998).

When constructing a taxonomic indicator, a data matrix composed of standardized features is used. Standardization allows you to get rid of the unit of measurement, both cost and natural. At the same time, the dispersion is leveled, as well as the values of the features, which is undesirable, because because of this, each feature equally affects the results of the analysis (Zhyhalkevych et al., 2018).

The initial data for positioning business structures according to the criterion "Possibility of attracting/providing innovations" were indicators that characterize extraversion (openness of innovations for external use) (Table 2).

The indicators that characterize introversion (the ability to use innovations for internal use) are given in Table 3. This formulation of the task allowed us to obtain a generalized picture of the changes that occur in the set of characteristics.

Table 2

Formulas for calculating innovation introversion indicators

Introversion Innovation Assessments	Calculation formula	Legend
Share of venture capital in total investment	Ki1= VC / I	VC – venture capital I – total investment
Number of innovations acquired (patents, licenses, copyrights, etc.)	Ki2 = OPI	OPI – the volume of acquired innovations (patents, licenses, copyrights, etc.) in monetary terms in a certain period of time
Indicator of expansion of innovation activity	Ki3 = OVNI / OVNA	OVNI – cost of acquired intangible assets for open innovation; OVNA – total cost of intangible assets
Indicator of attracted investments in innovative projects	Ki4 = EIIP / TCIP	EIIP – external investments in an innovation project; TCIP – total costs of an innovation project
Indicator of international openness to innovative products	Ki5 = VRSIP / TVORIP	VRSIP – volume of innovative products sold abroad; TVORIP – total volume of innovative products sold
The specific weight of partnership in the activities of the open innovation system	Ki6 = VPIP / TCIP	VPIP – partners' costs for the innovation project; TCIP – total costs for the innovation project

Source: author's compilation.

Table 3

Formulas for calculating innovation extroversion indicators

Innovation extraversion scores	Calculation formula	Legend
Share of revenues from open innovation	Ke1 = ROI / TRE	ROI – revenues from open innovations TRE – total revenues of the enterprise
Share of spending on open innovation	Ke2 = OIC / OI	OIC – open innovation costs; OI – total enterprise costs
Innovation attrition rate	Ke3 = VIADOI / TVIA	VIADOI – value of intangible assets that have been disposed of for open innovation; TVIA – total value of intangible assets
Outsourcing rate of non-core functions	Ke4 = OFO / VBP	OFO – the volume of functions outsourced; VBP – the total volume of business processes in the enterprise
Knowledge and technology transfer indicator	Ke5 = VIPSA / TVIP	VIPSA – volume of innovative products sold abroad; TVIP – total volume of innovative products sold

End of the Table 3

Innovation extraversion scores	**Calculation formula**	**Legend**
Percentage of information transfer to modern "open innovation" databases	Ке6 = PCIP / TCIP	PCIP – partners' costs for the innovation project; TCIP – total costs for the innovation project
Actual R&D performance	$К_{e7} = \frac{\sum R}{\sum_{i=1}^{N} Q_i - (H_н - H_к)}$	$\sum R$ – total costs for completed work; $H_н$ – costs for transitional (unfinished) work at the beginning of the time period; $H_к$ – costs for transitional (unfinished) work at the end of the time period; N – number of periods; Q_i – risky investments for the i-th period.

Source: author's compilation.

The next step in building a model of innovative development of business structures is to process the obtained characteristics according to the characteristics: introversion and extraversion of innovations. To do this, two initial matrices are compiled for each of the characteristics:

– matrix of introversion indicators: $K_{ii} = [K_{i1}; K_{i2}; K_{i3}; K_{i4}; K_{i5}; K_{i6}]$;

– matrix of extraversion indicators:

$K_{ei} = [K_{e1}; K_{e2}; K_{e3}; K_{e4}; K_{e5}; K_{e6}; K_{e7}]$.

We reduce these matrices to a dimensionless standardized form:

– introversion assessments: $k_i = [k_{i1}; k_{i2}; k_{i3}; k_{i4}; k_{i5}; k_{i6}]$, where $k_i = \frac{K_{ii}}{\overline{K_i}}$;

– extraversion scores: $k_e = [k_{e1}; k_{e2}; k_{e3}; k_{e4}; k_{e5}; k_{e6}; k_{e7}]$, where $k_e = \frac{K_{ei}}{\overline{K_e}}$.

We compose the reference matrices, where 0 is the best value in the columns:

– introversion assessments: $k_{i0} = [k_{i01}; k_{i02}; k_{i03}; k_{i04}; k_{i05}; k_{i06}]$;

– extraversion scores: $k_{e0} = [k_{e01}; k_{e02}; k_{e03}; k_{e04}; k_{e05}; k_{e06}; k_{e07}]$.

Moreover, for the compilation of standard matrices it is necessary to take into account that all indicators are differentiated by the degree of openness to innovations into stimulants and de-stimulators.

For example, stimulants for introversion are such indicators that increase the capabilities of business structures to attract innovations in their activities.

We determine the multidimensional Euclidean distance from it to each studied object, as well as the average value of the Euclidean distance from all objects to the standard by the formulas:

– for assessing introversion:

$$L_i^r = [(k_{i1} - k_{i01})^2 + (k_{i2} - k_{i02})^2 + (k_{i3} - k_{i03})^2 + \\ + (k_{i4} - k_{i04})^2 + (k_{i5} - k_{i05})^2 + (k_{i6} - k_{i06})^2]^{1/2}$$

$$\overline{L_i} = \frac{1}{I} \cdot \sum_{i=1}^{I} L_i^r ;$$

– to assess extraversion:

$$L_i^r = [(k_{e1} - k_{e01})^2 + (k_{e2} - k_{e02})^2 + (k_{e3} - k_{e03})^2 + (k_{e4} - k_{e04})^2 + \\ + (k_{e5} - k_{e05})^2 + (k_{e6} - k_{e06})^2 + (k_{e7} - k_{e07})^2]^{1/2};$$

$$\overline{L_e} = \frac{1}{E} \cdot \sum_{j=1}^{E} L_e^r ,$$

where I is the number of indicators by which business structures are evaluated in terms of introversion of innovations;

E is the number of indicators by which business structures are evaluated in terms of extraversion of innovations.

Further processing of statistical information is carried out by calculating the standard deviations of multidimensional distances and the corresponding generalizing indicators of the development of each business structure regarding introversion/extroversion of innovations:

$$\sigma^i = \frac{1}{I} \cdot \left[\sum_{i=1}^{I} \left(L_i^r - \overline{L_i} \right)^2 \right]^{1\backslash 2}, \sigma^e = \frac{1}{E} \cdot \left[\sum_{i=1}^{E} \left(L_e^r - \overline{L_e} \right)^2 \right]^{1\backslash 2} .$$

The indicator of the level of development of a business structure regarding introversion of innovation is a characteristic of its openness to involving open innovations in its activities, the indicator of the level of development of extraversion of a business structure is a characteristic of its ability to provide open innovations to partners and other enterprises interested in them. Thus, the taxonomy indicators for each of the assessments of the degree of openness to innovation are calculated using the following formulas:

$$\eta_i^r = 1 - \frac{L_i^r}{\overline{L_i} + 2\sigma^i}, \ \eta_e^d = 1 - \frac{L_e^r}{\overline{L_e} + 2\sigma^e}.$$

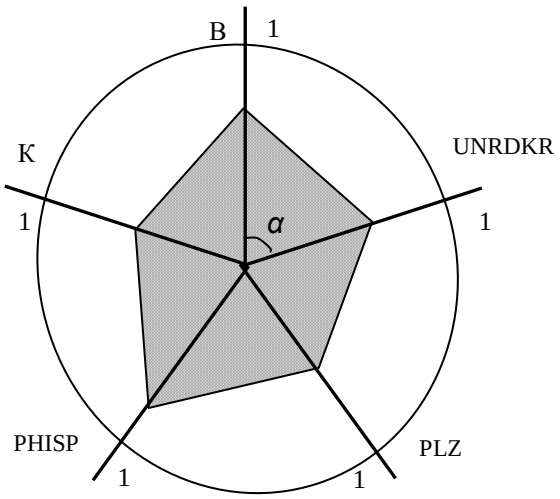
Quantitative analysis of the calculations of taxonomy indicators shows that the closer its value is to 1, the greater the degree to which the business structure is ready to attract or provide innovations.

If the use of taxonomy indicators as a quality in the coordinate system "Introversion / extraversion" will allow determining the position of the business structure in the proposed matrix according to the characteristic "Possibility of attracting / providing innovations", then the magnitude of this position is indicated by the size of the potential of the innovation system. Determination of the potential of business structures, including innovative (IP), according to the method of L.M. Hanushcha-Yefimenko (2009) is based on the use of the radar method, which is based on the calculation of integral indicators for each of the identified subsystems: production subsystem (B); R&D management subsystem, patent and license support subsystem (PLZ); financial and investment support subsystem for innovation projects (FIZIP); commercialization subsystem (K), where the potential value is taken as the area of the radar (IP) built inside the circle. The vectors of this radar are the integral indicators of the development of the subsystems of the innovation system, calculated by the taxonomy method (Fig. 7), where the area of the IP radar is determined by the formula:

$$S_p = 1/2 \sin\alpha \left(a_1 \cdot a_2 \cdot a_3 + ... + a_{n-1} \cdot a_n + a_n \cdot a_1\right),$$

where $a_1 ... a_n$ – the value of integral indicators of the development of innovative subsystems, in fractions of a unit;

α – angle between the nearest indicators, degrees.



Source: constructed by the author.

Fig. 7. **Theoretical view of the radar of the innovative potential of a business structure**

Effective modeling of innovative development of business structures in the post-war period will contribute to:

- acceleration of economic recovery of enterprises;
- increase of investment attractiveness;
- development of high-tech industries;
- creation of new jobs;
- strengthening of competitive positions of Ukrainian business in international markets;
- ensuring sustainable and inclusive economic development.

Conclusions and results of the study. Modeling the innovative development of business structures in the conditions of post-war recovery is a strategic management tool that combines economic forecasting, risk assessment, scenario planning and digital technologies. Its application allows you to form scientifically based strategies for the recovery of enterprises, effectively use limited resources and ensure the transition to an innovative model of economic development. For Ukraine, this is one of the key factors in successful post-war reconstruction, increasing international competitiveness and integration into the European economic space.

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