This paper has solved the task to improve the methodical approach to modeling the integrated index for assessing the level of innovation potential of the European Union countries as a component of the monitoring system. The object of the study is the process of ensuring the innovative development of the European Union; the subject is the model and methods for assessing the level of innovation potential. The relevance of the chosen topic corresponds to the processes associated with innovative development occurring in the world economy and economy of the European Union, as well as the need to evaluate them. Practical activities for integrated assessment of the level of development of innovative potential of countries are considered. Among the methods for assessing the innovation potential, the most widely used are the rating method, integral indices, and sets of indicators. The main disadvantages of the existing methods have been analyzed and outlined, which made it possible to improve the approach that enables to overcome the main problems outlined. An improved methodological approach to assessing the level of innovation potential of the European Union countries consists of a sequence of stages and allows formalizing the process of selecting the components of the integrated index and evaluating the weighting coefficients for these components. The improved methodological approach was tested on data on the innovative development of the countries of the European Union, which made it possible to identify groups of countries according to its level. The methodological approach can improve the analytical support for assessing the level of innovative development, highlight the weaknesses and strengths of the innovation ecosystems of the European Union countries, as well as increase the effectiveness of their innovation policy. The ways to overcome problems in disparities in innovative development between the countries of the European Union, as well as to increase the level of their innovative potential, are considered

Keywords: innovation potential, integrated index, key indicator, adaptive weighing, European Union

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IMPROVEMENT OF THE METHODICAL APPROACH TO ASSESSING THE LEVEL OF INNOVATION POTENTIAL OF THE COUNTRIES OF THE EUROPEAN UNION

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1. Introduction

Innovations are increasingly a prerequisite for the formation of a new model of a growing, highly productive, and competitive economy. The decisive advantages of the innovative model of economic development include four main ones [1]. First, innovation provides exceptional competitive advantages in the national and international markets. Secondly, innovative products have a higher added value. Thirdly, thanks to the diffusion of innovations and the constant process of improvement, innovations become more efficient and acquire new consumer properties and, in conclusion, innovations stimulate the creation of new market niches.

Among the key tasks of creating a sustainable infrastructure and promoting industrialization and innovation declared by the United Nations in the System of Global Indicators for achieving sustainable development goals by 2030 [2], the following should be highlighted:

– intensification of scientific research, increasing the technological potential of industrial sectors in all countries, especially in developing countries. Stimulation by 2030 of innovation and a significant increase in the number of workers in the field of research and development per 1 million population, as well as public and private spending on research activities;

– to support development, research, and innovation in the field of domestic technologies in developing countries, including through the creation of a political climate contributing, in particular, to the diversification of industry and increase in added value in raw materials industries;

– to significantly expand access to information and communication technologies and strive to ensure universal and inexpensive access to the Internet in the least developed countries;

– by 2030, modernize infrastructure and re-equip industrial enterprises, make them sustainable by increasing the efficiency of resource use and wider use of clean and environmentally friendly technologies and industrial processes.

Based on the declared tasks, innovative development becomes not only a model of development of individual countries of the world but a requirement for society and sustainable global development.

The implementation of the task of increasing the rate of economic growth on the basis of an extensive path of development, without qualitative structural changes in the economy itself, leads to a decrease in the level of its competitiveness. This, in turn, entails the displacement of products from international markets. The transition to an innovative path of development is associated with neo-industrial transformational changes in the global economy, the growth of its digitalization and increased competition in international markets. The specialization of each country, its geographical, climatic, socio-cultural, and other features, as well as its own specificity and model of economic development, creates features of the formation and use of innovative potential. These processes affect the unevenness of global innovation development. The creation of a national innovation-oriented economy is based on a coordinated national policy of innovative development, which cannot exist without an effective monitoring system. In this regard, the development and improvement of monitoring tools is becoming important, which will allow a more objective assessment of the country's innovative potential, highlight weaknesses and strengths, as well as actively implement a sound innovation policy.

Improving the model range of components of the system for monitoring the innovative potential of the state will lead to an increase in the degree of its formalization. It will also increase the efficiency of the levers of the management system to support the development of innovative potential, through the development of reasonable priorities and principles for managing innovative development.

The economies of the European Union should be attributed to the traditional models of the full innovation cycle, which implement and support innovative development from the emergence of an innovative idea to its implementation in the production of finished products. Also in these models is an important role of the state, which contributes to the development of an innovative ecosystem. The innovation ecosystem in the traditional model is represented by all the components that ensure innovative development: fundamental and applied science, institutional support, funding for research from the public and private sectors, a developed market, high-tech production. It is the study of traditional models of the full innovation cycle that will make it possible to deepen knowledge of the directions of innovative development and form recommendations for developing countries to ensure the sustainable development of the global economy.

Based on the foregoing, it can be argued that the development of new and improvement of existing approaches to the integral assessment of the innovative potential of the European Union countries is an urgent task.

2. Literature review and problem statement

Analysis of literary sources [3–18] related to the study of the innovative potential of the countries of the European Union allowed us to identify the main directions of relevant research. These areas can be divided into the following groups:

– formation of new approaches and improvement of existing to assess the level of innovative potential of the European Union countries;

– study of the determinants of the development of innovative potential of these countries and regions;

– innovation policy and formation of new approaches to the management of innovative potential;

– evaluation of the effectiveness of the use of innovative potential.

Paper [3] formed an approach to assessing the level of innovation potential of the European Union countries on the basis of multidimensional statistics and rating approach. Also, study [4] proposed new approaches to assessing the level of innovation potential of the European Union, based on ranking. But the issues of a comprehensive indicator approach to assessing the level of innovation potential still remain unresolved.

The issues of choosing indicators for assessing the innovation activity of medium and small enterprises in the European Union are covered in [5]. Based on the obtained indicators, the authors propose to predict the dynamics of the development of these enterprises. But the assessment of the innovation activity of medium and small enterprises does not give a complete picture of the state of innovation potential of the countries of the European Union but is part of it.

The problems of assessing the level of innovation potential of Eastern European countries are considered in [6]. The author uses correlation-regression analysis to identify factors influencing the innovative potential of Eastern European countries. In [7], the issue of assessing the level of innovation potential of small and medium-sized businesses in Spain is studied. Internal organizational factors, belonging to a specific industrial sector, human resource management as incentives for the innovative development of these enterprises are considered. But focusing on individual countries or groups of countries does not give a complete answer to the level of innovation potential and development of all member states of the European Union as a powerful regional entity. This makes it impossible to study the experience of leading countries and its projection on countries with lower potential levels.

The study of the determinants of the development of innovative potential of the countries and regions of the European Union was carried out in works [8–11]. Issues of regional development and innovation in the European Union are widely covered in [8]. The authors explore the impact of many factors of innovation on the regional development of the European Union. Particular attention is paid to the spatial view of innovation and economic growth, namely the influence of human capital, flow of knowledge and investment in research and development for innovative development. But the issues of forming tools for identifying factors and assessing the level of their influence on the innovative development of the European Union remain unresolved.

A review of financial instruments for promoting business innovation in the European Union in the context of Industry 4.0 was conducted in [9]. The work of another author [10] explores the interaction between social capital, innovation, and economic growth in the European Union. Study [11] analyzes cause-and-effect relationships and geographical measurements of the impact of innovation potential, the level of education on the economic development of the European

Union. But it can be argued that the allocation of certain determinants of influence on the innovative potential of the countries of the European Union does not make it possible to form a set of tools and levers of policy in the field of innovation to ensure sustainable development.

The formation of new approaches to the management of innovative potential and innovation policy are discussed in [12–14]. In [12], the author analyzes various concepts and answers the question of whether the European Union can be attributed to innovative systems. Based on an interdisciplinary approach, he analyzes the processes of institutional construction of the innovative system of the European Union. The work of other authors [13] analyzed the dynamics of changes in the innovative system of the European Union, as well as the emergence of national innovative cultures. But these studies focus on certain aspects of the formation of the innovative potential of the European Union while an integrated approach to the study of this problem remains unresolved.

The legal framework and innovation policy in the European Union is considered in [14]. The authors explore and develop new approaches to defining innovations, their effectiveness, innovation policy management, as well as key policies in the field of innovation and expectations from them in the future. But this study is theoretical in nature, which does not give a full-fledged answer to the question about the state of policy in the field of innovation and the improvement of its tools.

Evaluation of the effectiveness of the use of innovative potential of the European Union countries is considered in works [15–18]. Thus, disparities in regional development and the use of innovative potential and the impact of research and development financing on its development are considered in [15]. Similar issues of the effectiveness of European policy in the field of research and development are considered in [16]. The authors proved that investments in development and research have a positive effect on innovative development but the socio-economic differentiation of each region affects their ability to turn into economic growth. But it should be noted that focusing attention and widespread growth of financial and investment instruments distracts attention from other instruments, which in the long run can lead to a drop in the efficiency of innovation.

Another paper [17] analyzes the scale and effectiveness of supporting the innovative potential of small and medium-sized businesses in the European Union. It is determined that the greatest impact on the level of innovative development of small and medium-sized businesses is exerted by external non-repayable financial support from various funds and technological support of the European Union. But the issues of supporting academic and fundamental science as a basis for the prospective development of the innovative potential of the countries of the European Union remain unresolved.

Studies of the effectiveness of public administration and innovation in the regions of the European Union were carried out in [18]. The authors analyzed the positions of the Member States of the European Union on innovation. These positions are evaluated from the aggregation of various data characterizing innovative development. But it should be noted that the authors do not consider an aggregated single indicator as an assessment tool, they focus on the analysis of different sectors in each country, which complicates the process of interpreting the data and understanding the results of the study.

The analysis of literary data [3–8, 10, 11] suggests that it is expedient to conduct a study aimed at improving the methodological approach to assessing the level of innovation potential of the European Union countries on the basis of an integrated index as part of a monitoring system.

3. The aim and objectives of the study

The aim of this study is to improve the methodological approach to assessing the level of innovation potential of the European Union countries as part of the monitoring system. This will increase the analytical support for the stages of development of innovation ecosystems in the countries of the European Union, as well as develop recommendations for improving the efficiency of innovation and innovation policy in the countries of the European Union.

To accomplish the aim, the following tasks have been set:

– to identify the peculiarities of existing practical approaches to assessing the level of innovative development or potential of the European Union countries;

– to devise an integrated index for assessing the level of innovation potential of the European Union countries.

4. The study materials and methods

The object of the study is the process of ensuring the innovative development of the European Union. Under the innovative potential of the country we understand the system of organizational forms, methods, and tools by which the country's ability to effectively and accurately use the available resources and the existing innovation environment is achieved. This, in turn, stimulates the creation and implementation of innovations in social production to ensure a highly productive, competitive, and growing economy that is able to generate exports of goods and services with high added value.

Management of innovation potential should be based on the following principles:

– balance of innovation potential with the structure and economic potential of the state;

– efficiency of use of available resources and those that are involved;

– social utility – innovative development should increase labor productivity, create new jobs in the economy, increase the economic well-being of society [19];

– adaptability and flexibility of innovative potential for change, which is manifested in the constant response to external and internal multidirectional positive and negative challenges, due to which changes occur, improvement of processes based on the transformation of existing resources into qualitatively new states;

– innovation capacity and technical readiness for innovation, which is associated with a conservative culture, or the readiness of infrastructure for innovation;

– advanced cyclical nature [20] – the development of new innovative products and services should begin when ready-made innovative products are just being introduced to the market.

Management of innovative potential allows one to provide conditions for stable economic growth, increase the country's competitiveness and investment attractiveness, increase ex-

ports of high-tech products, coordinate the macroeconomic policy of states, and ensure the economic security of the state. The level of development of the country's innovative potential depends on a large number of factors that cannot be fully taken into account, and they also affect the effectiveness of innovative development in different ways, which also makes it impossible to fully take into account their impact. All this forms the need to improve approaches to the formation of approaches to modeling the assessment of the level of innovation potential of the countries being studied.

From the review of literary sources [3–7], there are three groups of methodological approaches to assessing the level of innovation potential of countries. The first methodical approach is based on the use of a set of indicators selected in a logical way or another and the conditions on the basis of which the country belongs to a particular group are formed. The second group of methodological approaches includes rating methods. These methods are a set of stages at which a set of indicators-characteristics is formed, after which they are ranked or aggregated and combined into a separate indicator, and at the final stage a rating is built. The third, most widely represented group of methodological approaches, should include integral (synthetic) indices, allowing a more formalized approach to the process of building an integral indicator. Most often, researchers use an integral model of the index in the form of the sum of the products of the aggregated selected indicator and the weight coefficient. Also, one of the advantages of integral indices is their clarity for a wide range of consumers of relevant information.

5. Results of studying the level of innovation potential of the European Union countries

5. 1. Results of studying the features of existing practical approaches to assessing the level of innovative development of the European Union countries

For the effective implementation of innovation policy, a necessary condition is information and analytical support for innovative development at all levels of management, which can be achieved through the introduction of a monitoring system for the innovation ecosystem of the European Union countries and its effectiveness. One of the important components in the monitoring system are models and methods of processing and analyzing information [21], which makes it possible to objectively assess the state, features and predict the prospects for innovative development of the country's economy. Innovation potential is a complex concept and consists of a set of indicators. It also depends on a large number of factors that can be estimated by various metrics, most often aggregated indicators and integral indices are used for evaluation, which may include a large set of data.

In practice, there is a wide range of global and regional indicators and indices to assess the level of development of innovative potential and innovation activity of countries. Indicators and scorecards developed and calculated by various international organizations become tools that are widely used by foreign investors, governments, organizations, business owners to analyze innovation activity and innovation policy of states.

Among the authoritative benchmarks of estimated data on trends in global and regional innovation development is the Global Innovation Index [22], which is published by the World Intellectual Property Organization. The data have been published since 2007, which are a source of information for the development of strategies for innovative development and an analytical tool for improving the system and components of innovation policy of states. Global Innovation Index scores 81 indicator in the following main seven areas: institutions, human capital and research, infrastructure, market development level, results in the field of knowledge and technology, results of creative activity.

According to the results of the published report of the World Intellectual Property Organization on the results of the assessment of the Global Innovation Index in 2022 [23], the maximum number of the world's leading innovative economies is concentrated in the European region – 15. Of the 27 countries in the European Union, 11 countries improved their ranking in 2022. The greatest dynamics are observed in the following countries: Malta (+6), Luxembourg (+4), Estonia (+3), Greece (+3), Poland (+2), and Germany (+2). Moderate positive dynamics are in the following countries: the Netherlands (+1), Austria (+1), Cyprus (+1), Italy (+1), and Spain (+1). The results of the assessment of the Global Innovation Index for the European Union countries in 2021–2022 are given in Table 1.

Table 1

Ranking of the European Union countries by the level of the Global Innovation Index in 2021–2022 [22]

Country	2022		2021	
	Rank	Score	Rank	Score
Sweden	3	61.56	2	63.10
Netherlands	5	58.04	6	58.63
Germany	8	57.23	10	57.32
Finland	9	56.88	7	58.36
Denmark	10	55.93	9	57.34
France	12	54.96	11	54.96
Austria	17	50.19	18	50.85
Estonia	18	50.19	21	49.92
Luxembourg	19	49.81	23	49.04
Malta	21	49.15	27	47.12
Ireland	23	48.54	19	50.66
Belgium	26	46.88	22	49.17
Cyprus	27	46.17	28	46.73
Italy	28	46.06	29	45.70
Spain	29	44.62	30	45.39
Czech Republic	30	42.84	24	49.02
Portugal	32	42.11	31	44.24
Slovenia	33	40.56	32	44.14
Hungary	34	39.83	34	42.68
Bulgaria	35	39.53	35	42.36
Poland	38	37.55	40	39.85
Lithuania	39	37.35	39	39.88
Latvia	41	36.53	38	39.98
Croatia	42	35.60	42	37.27
Greece	44	34.54	47	36.32
Slovakia	46	34.30	37	40.19
Romania	49	34.11	48	35.62

Another authoritative index is the Bloomberg Innovation Index (Bloomberg Innovation Index) [24]. The

agency publishes its own ranking for 60 countries (in 2015 the index was published for 50 countries). The index takes into account the following groups of indicators: research expenditures, labor productivity, high-tech density, concentration of research personnel, technological capabilities, patent activity, efficiency of higher education. According to the results of 2021, all countries of the European Union were included in the ranking of Bloomberg, among the leaders are the following countries: Germany (4th place in the world ranking), Sweden (5th place), Denmark (6th place), Finland (8th place), and the Netherlands (9th place). And among the outsiders of the ranking of the European Union countries are the following: Bulgaria (41st place), Malta (42nd place), Slovakia (44th place), Croatia (45th place), Cyprus (49th place) [25].

More interesting is the European Innovation Scoreboard [26], which is a comparative regional indicator showing the effectiveness of innovation activities of the European Union, as well as other European neighboring countries. The index was first calculated in 2001. Over twenty years, this index has been significantly transformed, its latest version updated in 2021. This index allows us to demonstrate the strengths and weaknesses of national innovation ecosystems of the Member States of the European Union. The European Innovation Scoreboard Index includes four equally weighted groups of indicators:

– "Framework conditions" (subgroups: "Human resources", "Attractive research systems", "Digitalization");

– "Investments" (subgroups: "Finance and financial support", "Private investments", "Use of information technology");

– "Innovative activity" (subgroups: "Innovators", "Connections", "Intellectual assets");

– "Impacts" (subgroups: "Impact on employment", "Impact on sales", "Environmental sustainability"), which include the same number of indicators. In total, the innovation scoreboard covers 32 different indicators. After evaluation, depending on the level of the country index, they are classified as different groups: "innovative leaders", "strong innovators", "average innovators", "modest innovators" [27].

The results of assessing the level of innovative development of the European Union countries based on the European Innovation Scoreboard Index for 2021–2022 are given in Table 2.

As can be seen from Table 2, the countries with a decrease in innovation activity include the following: Estonia (–8.9), Malta (–4.6), Romania (–2.9), Italy (–2.9), Germany (–1.7), France (–1), Latvia (–0.7). Conversely, the most innovatively active countries according to the results of the assessment in 2022 were the following: the Czech Republic (+11.7), Ireland (+7.7), Finland (+7.5), Lithuania (+6.3), Cyprus (+5.9), Spain (+5.5). Among the "innovative leaders" of the European Union are traditional innovators: Sweden, Finland, Denmark, the Netherlands, Belgium. According to the results of the report [29], the effectiveness of innovation activity increased by 10 % compared to 2015, and the situation of the European Union countries has significantly strengthened in the world.

In addition to the described indicators for assessing the level of innovation activity of countries, in international practice, complexes of sets of indicators and integral indices are used. For example, OECD Innovation Indicators [30], The Global Talent Competitiveness Index [31], and others.

Table 2

The value of the European Innovation Scoreboard Index and the ranking of the European Union countries by its level in 2021–2022 [28]

Country	2022		2021		Difference
	Index	Rank	Index	Rank	
Sweden	149.1	1	147.4	2	1.7
Finland	148.9	2	141.4	3	7.5
Denmark	148.1	3	147.7	1	0.4
Netherlands	142.1	4	140.1	4	2
Belgium	141.5	5	137.2	5	4.3
Ireland	130.7	6	123.0	9	7.7
Luxembourg	130.4	7	130.8	7	–0.4
Austria	130.1	8	128.6	8	1.5
Germany	129.2	9	130.9	6	–1.7
Cyprus	117.4	10	111.5	12	5.9
France	115.9	11	116.8	11	–1
Estonia	109.8	12	118.7	10	–8.9
Slovenia	102.7	13	99.7	14	3
Czech Republic	101.7	14	90.0	18	11.7
Italy	100.7	15	103.6	13	–2.9
Spain	97.5	16	92.1	17	5.5
Portugal	94.3	17	92.2	16	2.1
Malta	93.0	18	97.6	15	–4.6
Lithuania	92.0	19	85.6	19	6.3
Greece	88.2	20	84.5	20	3.7
Hungary	76.7	21	73.8	21	3
Croatia	73.0	22	71.1	22	2
Slovakia	70.7	23	66.1	23	4.6
Poland	66.5	24	62.2	24	4.3
Latvia	55.8	25	56.6	25	–0.7
Bulgaria	49.7	26	46.7	26	3
Romania	35.9	27	38.7	27	–2.9

5. 2. Development of an integrated index for assessing the level of innovation potential of the European Union countries

One of the drawbacks of the rating assessment of innovation potential is its endogeneity of evaluation. The change of place in the rating may be associated not with transformational changes in the country's economy but with a decrease in innovation activity in another country, and as a result, changes in the rating. Another of the negative aspects of the rating is the coverage of a large number of indicators (more than 80), which ultimately averages the final results of the assessment too much. This does not make it possible to single out the key "locomotives" of innovative development and the factors restraining innovation activity. When including a wide range of indicators, the model may also not be justified and will require constant review.

In some methods for assessing the level of innovation potential, which are based on the calculation of the integrated index, weights are determined by expert means, which introduces a high degree of subjectivism to the final result of the assessment.

Also, an analysis of the dynamics of various indices shows that they sometimes carry asynchronous and acyclic dynamics, and their values differ significantly from each other, which also needs clarification and revision. And during

the audit of the components and their weights, the content of the indices changes, which does not allow for an objective comparison and assessment of the dynamics of the innovative potential of the countries being studied.

In addition, integral and complex indicators are difficult to interpret based on the results of the assessment. When expanding the number of indicators, they can duplicate each other, which gives a distortion of the final results of the assessment. Given the shortcomings of the considered methods, an objective need is to improve them, namely:

– models that are components of the methodology should be grouped on the use of formalized approaches to the selection and analysis of components of innovation potential;

– improved traditional statistical methods for assessing innovation potential, which will make it possible to obtain more objective results;

– development of an adapted approach to assessing the weighting factors of the components of the innovation potential, which will allow changing their values depending on the stage of the innovation cycle. The use of an adaptive approach allows you to focus on those levers of innovation policy of the state that will allow it to be more effectively implemented.

To address these shortcomings, an integrated index of innovation potential for the countries of the European Union has been developed. The methodical approach to the calculation of the integrated index consists of a sequence of stages, each of these stages is described in detail below:

1. At the first stage of the development of the integrated index, the selection of indicators that can potentially be included in its composition is carried out. Information sources for the selection of indicators were the current open statistics of Eurostat [32], the Organization for Economic Cooperation and Development [33], the World Bank [34]. The main requirements for the selection of indicators are as follows: availability of sources of information and completeness of information. According to the results of this stage, 28 indicators were selected that demonstrated the main directions of science, technology, and innovation development of the European Union:

– gross domestic product, million euro;

– venture capital investment, million US dollars;

– resource productivity and internal efficiency, euros per kg.;

– the volume of exports of goods, thousand euro;

– the number of employed, thousand people;

– the number of employed persons with higher education, thousand people;

– the percentage of employed ICT specialists to the occupied persons;

– the number of employed ICT specialists;

– the percentage of enterprises using big data analysis;

– percentage of enterprises using integration with customers / suppliers, supply chain management;

– the percentage of workers who use the Internet in the workplace;

– percentage of enterprises with a high digital intensity index;

– the number of people with higher education, thousand people;

– persons with higher education (ISCED) and/or employed in science and technology, thousand people;

– employment in technological and knowledge-intensive sectors, persons with higher education, thousand;

– high-tech exports – the share of exports of high-tech products in total exports, as a percentage;

– high-tech exports, million euro;

– import of high technologies, million euro;

– export of high technologies, million euro;

– the number of enterprises in high-tech industries;

– budget expenditures for research and development, million euro;

– research staff at the national level, individuals;

–expenses of enterprises for research and development, million euro;

– gross domestic expenditures of the non-profit private sector for research and development, million euro;

– gross domestic expenditures of higher education for research and development, million euros;

– gross domestic expenditures of the non-profit private sector for research and development, million euros;

– gross domestic expenditures of governments for research and development, million euros;

– gross domestic expenditures of the business sector for research and development, million euros.

According to some indicators, current statistics were available only for 2020, so it was decided to form a database for that year.

2. To identify abnormal values, errors and significant emissions in statistical data, their analysis is carried out on the basis of the criterion of "three sigma". If the criterion was exceeded, the data were replaced by the values of three standard deviations from the average value of the indicator by country.

3. At the next stage, a justification is made for the choice of a key indicator reflecting the potential for innovative development. Due to the fact that in practice there is no single indicator that would reflect innovative development, potential and its effectiveness, it was proposed to choose the value of gross domestic product by the countries of the European Union.

4. At the fourth stage of construction of the integrated index of innovative development of the European Union, the indicators selected for the database are normalized on the basis of the methodology proposed in the Methodological Report of the European Innovation Scoreboard [27]. The normalization technique is the determination of the minimum and maximum values by stimulant indicators within each group of values by country and the calculation of the scaling ratio:

$$\bar{X}_i^j = \frac{X_i^j - X_{\min}^j}{X_{\max}^j - X_{\min}^j}, \quad (1)$$

where X_i^j is the value of the indicator for the i-th country in the j-th group of indicators;

$X_{\max}^j$, $X_{\min}^j$ – the maximum and minimum values for the j-th group of indicators, respectively.

Grouping of indicators is carried out by areas of their origin to assess the impact of individual areas of economic activity on the level of innovation potential of countries.

It is advisable to scale up for an isolated group of a set of objects that are united on separate grounds, as in our study – the countries of the European Union.

5. After bringing the indicators into a comparable form, the indicators are selected based on the calculation of the linear paired correlation coefficient between the key indicator and each selected indicator (r_j). Indicators that

are stimulants are selected subject to the existing system connection, the value of correlation indicators should be r_j>0.4, that is, the systemic connection should be from moderate to essential, on the Chaddock scale. In addition, a logical analysis of the selected indicators is carried out when they duplicate each other, left is the one that has the highest value r_j. Also, the correlation coefficient is checked for significance.

6. At this stage, the calculation of weight coefficients is carried out with the selected indicators. To calculate the weighting factors, the adaptive weighing technique is used, which was developed by the authors earlier and described in works [35, 36]. The technique is that the square root of the square of the difference between the normalized indicators $\overline{X}_i^j$ and the normalized key indicator $\overline{I}_i$ should be calculated:

$$d_i^j = \sqrt{\left(\overline{X}_i^j - \overline{I}_i\right)^2}. \quad (2)$$

After that, the weighting coefficients are calculated based on the ratio:

$$w_j = \frac{\sum_{i=1}^{n} 1/d_i^j}{\sum_{j=1}^{m}\sum_{i=1}^{n} 1/d_i^j}, \quad (3)$$

where n is the number of countries studied (in our case, 27 countries of the European Union);

m – the number of selected j indicators for inclusion in the model;

$$\sum_{j=1}^{m} w_j = 1.$$

The basis of the calculation of ratio (3) is the assumption that the weight of the selected indicator will be greater with a smaller amount of distances (2). The use of this technique formalizes the process of evaluating weight coefficients and avoids subjective expert influence on the simulation results.

The results of the selection of indicators and the calculation of weight coefficients are given in Table 3.

7. Further, a model of the integrated index of innovative potential of the countries of the European Union ($3IP_i$) is constructed as a linear combination of the product of selected indicators and weight coefficients of the type [35, 36]:

$$3IP_i = 100\sum_{j=1}^{m} w_j \overline{X}_i^j. \quad (4)$$

The closer the value of $3IP_i$ to one hundred, the more powerful is the innovative potential of the country of the European Union. The integrated index of innovation potential shows the power of the country's innovative potential in the group of countries of the European Union.

The implementation of the proposed methodological approach made it possible to obtain a practical model of the integrated index of innovative potential of the countries of the European Union, which has the following form:

$$3IP_i = \begin{pmatrix} 0.093V_i + 0.026R_i + 0.095E_i + \\ +0.078H_i + 0.071Q_i + 0.148T_i + \\ +0.345P_i + 0.144B_i \end{pmatrix} \cdot 100. \quad (5)$$

Table 4 presents the calculated values of the integrated index of innovative potential of the European Union countries in 2020.

Table 3

Results of calculations according to the fifth and sixth stages of the methodology

Indicator	Conditional value	Correlation coefficient	Weighting factor
Venture capital investments, US Dollar, millions	V_i	0.915	0.093
Resource productivity and domestic material consumption, euro per kilogram	R_i	0.452	0.026
Employment tertiary education (levels 5–8), thousand persons	E_i	0.931	0.095
Exports of high technology products in million euro	H_i	0.814	0.078
Enterprises in high-tech sectors, number	Q_i	0.749	0.071
Total government budget allocations for R&D, million euro	T_i	0.967	0.148
R&D personnel, people	P_i	0.993	0.345
Expenses of enterprises for research and development, million euros (BERD, million euro)	B_i	0.954	0.144

Table 4

Values of the integrated index of innovative potential of the European Union countries in 2020

Country	3*IP*
Germany	98.61
France	61.09
Italy	32.49
Spain	30.03
Netherlands	28.95
Poland	20.01
Sweden	15.80
Belgium	15.66
Austria	11.30
Czech Republic	10.72
Denmark	9.26
Ireland	8.63
Finland	8.33
Hungary	7.36
Portugal	5.92
Greece	5.80
Romania	4.31
Slovakia	4.17
Luxembourg	2.92
Bulgaria	2.48
Slovenia	2.32
Croatia	2.11
Lithuania	1.65
Latvia	1.05
Estonia	0.99
Malta	0.92
Cyprus	0.67

Fig. 1 demonstrates the relationship between economic development and the values of the developed index for each of the countries of the European Union.

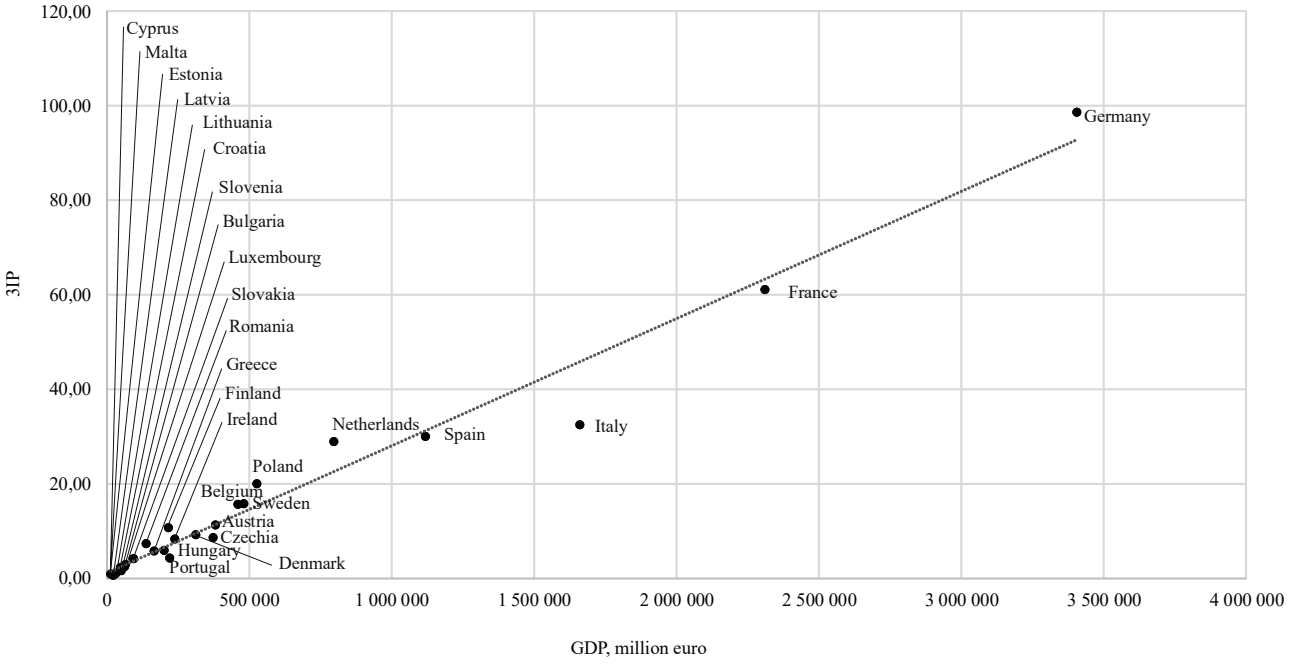

Fig. 1. Demonstration of a direct relationship between the country's innovation potential (the value of the integrated index of innovation potential) and its economic development (the level of gross domestic product)

As can be seen from Fig. 1, there is a close direct relationship between the calculated values of the integrated index and the economic development of the countries of the European Union, which confirms the adequacy of the developed index and its model characteristics. Another of the conclusions is that there is a significant differentiation between the countries of the European Union, they can be visually divided into three main groups:

– "Innovative giants" demonstrate high results of innovation potential and economic development: Germany, France, Italy, Spain, and the Netherlands;

– "Innovative athletes" demonstrate the average values of innovation potential and economic development: Poland, Sweden, Belgium, Austria, Czech Republic, Denmark, Ireland, Finland, Hungary, Portugal, Greece, Romania, Slovakia;

– "Moderate innovators" demonstrate low innovation potential: Luxembourg, Bulgaria, Slovenia, Croatia, Lithuania, Latvia, Estonia, Malta, Cyprus.

Also, as can be seen from Fig. 1, in the first group of countries, Italy inefficiently uses its innovative potential while Germany and the Netherlands, on the contrary, are more effective.

6. Discussion of results of assessing the level of innovation potential of the European Union countries

The obtained results based on the calculation of the integrated index of innovative potential of the countries of the European Union (Table 4) allowed us to divide the countries of the European Union into groups according to the level of innovation potential. This allows us to conclude that there is a significant differentiation between the countries of the European Union in terms of the level of innovation potential and the effectiveness of its use (Fig. 1). The obtained model of the integrated index (5) demonstrates that the locomotives of innovative development are human resources and funding for research and development from various sources.

The advantages of the improved methodological approach, in contrast to the considered author's indices [3–5, 7] and indices of international institutions [22–24, 26], include a formalized approach to the selection of index components and the assessment of weighting coefficients. Thus, the methods in [22, 24, 26] are based on expert evaluation, the developed methodological approach makes it possible to reasonably choose the components of the innovative potential. And the procedure for assessing weighting coefficients allows to obtain more objective results of the system for monitoring innovative development, by formalizing the procedure for selecting and weighing the components of the level of innovation potential.

The obtained results of assessing the level of innovation potential of the European Union countries and its key indicators (Table 4), as well as the considered current statistics [32–34], allow us to form the following general conclusions:

1. Analysis of the existing world rankings of innovative development demonstrates that the European Union remains one of the centers of global innovative development.

2. In 2020–2021, the Covid-19 pandemic became the main challenge for innovative development, which affected economic growth rates and labor productivity but this, in turn, pushes for deeper digitalization of the infrastructure of the European Union countries.

3. In 2022–2023, the innovative development of the European Union will be affected by instability in energy markets, Russia's aggressive war against Ukraine, and changes in geopolitical guidelines.

4. From a review of the literary data [3–18] and the study of statistical indicators of innovative development [22–24, 26, 32, 33, 34], it can be concluded that the restraining conditions and negative factors of innovative development of the European Union are:

– a significant gap in the pace of innovative development and the power of innovation potential between countries, which will deepen;

– existing "gravitational innovation centers" attract researchers from other countries, which "washes out" the driving forces of innovative development;

– incomplete consideration of problems and stimulating factors by countries with low indicators of innovation potential;

– distraction from innovative development goals due to external and internal instability.

To address these problems, the governing bodies of the European Union and the participating countries need to form the following areas for improving innovation policy:

– strengthening state institutional support for priority areas of innovation;

– expansion of targeted programs to support science in academic institutions, increase in grant and program-targeted funding;

– active support of programs for private financing of scientific and technical developments;

– increasing funding for state programs to order innovative products;

– thorough analysis of individual accepted programs and projects of innovative development in order to increase the efficiency of innovation;

– stimulating the creation of innovation clusters, techno parks, technopolises, innovation centers;

– improvement of the information and analytical system of monitoring and forecasting at all stages of the innovation cycle at the level of the European Union states;

– development of innovative culture and stimulation of innovative entrepreneurship in society;

– revision of the choice of individual areas of financing of scientific developments due to their low efficiency;

– formation of educational programs and their popularization in the field of innovative entrepreneurship and innovative management;

– increasing the budget and popularizing STEM specialties;

– reduction of differentiation between countries according to the level of innovative development;

– stimulating the development of venture funds and non-institutional investors;

– widespread use of state credit guarantees and risk sharing;

– expansion of direct financing programs through equity;

– strengthening ties between all subjects of innovation ecosystems of countries;

– improving the regulatory environment for innovation policy;

– careful monitoring of the country's innovation ecosystem, dominant economic growth, negative factors, and innovation activity;

– ensuring the dissemination of information on the state of innovation and key indicators of innovative development of states;

– professional development of civil servants at all levels, ensuring the formation and revision of the state innovation policy;

– deepening international relations in the field of technology exchange and scientific and technical community;

– intensification of informational, educational and exhibition activities in the field of new technologies, innovative products, and innovation activities;

– deepening digitalization into all components of the country's innovation ecosystem to accelerate and stimulate economic growth.

Among the main limitations of this methodological approach is that it analyzes intragroup interaction in the innovation environment of the Member States of the European Union and does not allow comparing the innovation potential with other countries.

Among the shortcomings of the improved methodological approach are the following:

– the choice of a key indicator significantly affects the results of selection and inclusion of indicators in the model of the integrated index;

– the need to adjust the components of the model and weighting coefficients, due to the fact that the simulation of the integrated index is based on time series;

– the index model is based on the absolute values of indicators, which complicates their comparison and further research.

To solve these shortcomings of the methodological approach, in the future, the main directions of research development related to the improvement of the developed integrated index of innovative potential of the European Union countries are the following:

– transition to relative indicators of the components of the integrated index in order to eliminate the influence of the internal structure of capacities of the countries of the European Union;

– annual audit of the components of the index and adjustment of weighting coefficients due to changes in the macroeconomic situation in the countries of the European Union;

– use of new tools and methods of analysis and modeling of the integrated index;

– updating and accumulating additional information, as well as taking into account dynamic data in the index.

7. Conclusions

1. The peculiarities of existing world practices for assessing the level of potential of countries are considered, which made it possible to highlight the main shortcomings of existing approaches, namely: rating assessments have a significant endogeneity of evaluation, and the coverage of a large number of indicators too averages the final results. Constant review of indicators makes it impossible to compare the results in retrospect. The selection of the components of the indicator and the determination of their weight coefficients by expert means introduces a high degree of subjectivism to the results of the calculation of the integrated index.

2. An integrated index has been developed that demonstrates the relative power of innovation potential within a group of European Union countries. Its features are that the procedure for obtaining it consists of a sequence of stages and allows you to formalize the process of selecting and evaluating the components of the integrated index of innovation potential. Thanks to the developed integrated index, the conditions for the formation of the innovative potential of the European Union countries are investigated. The key factors for the success of using the innovation potential are the balance of all its components, that is, the developed innovation ecosystem of countries. The locomotives of innovative development are human resources and research and development financing. The restraining conditions and negative factors of innovative development of the European Union remain a significant gap in the pace of innovative development and the capacity of innovation potential between

deepening countries. Existing "gravitational innovation centers" attract and "wash out" intellectual capital from other member countries. As well as increased distraction from innovative development goals due to instability in energy markets and Russia's aggressive war against Ukraine. Ways to increase the level of innovative potential of the European Union countries on the basis of financial, institutional, and socio-economic levers are proposed.

Conflicts of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study and the results reported in this paper.

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Data availability

The manuscript has related data in the data warehouse: Eurostat [32], Organization for Economic Cooperation and Development [33], World Bank [34].

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