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PROGRESS TOWARDS THE INNOVATION POTENTIAL OF THE EUROPEAN UNION MEMBER STATES USING GREY RELATIONAL ANALYSIS AND MULTIDIMENSIONAL SCALING METHODS

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Abstract: *The article presents the results of a study aimed at assessing the level of innovation potential of European Union member states. The research was based on 8 diagnostic variables characterizing the two most important dimensions of innovation, namely human resources and R&D expenditures. As a result of the research, the levels of innovation potential of European Union countries between 2010-2020 were specified. The GRA approach and multidimensional scaling were used for the study. Based on the results, the European Union countries were divided into 4 classes. The findings showed large differences in this potential across countries, which was graphically illustrated by using the multidimensional scaling method. In addition, using two non-parametric tests, (Spearman Rank Correlation Coefficient and Kendall Correlation Coefficient), relationships between the innovation potential of member states and selected economic and innovation parameters of their economies were determined. The results of the study indicate that in the old EU-14 countries, this level was at a significantly higher level than in the new EU-13 countries. The EU-27 innovation potential leaders were found to be Finland, Sweden, Luxembourg, Denmark, and Germany. The worst performers, on the other hand, are Malta and Romania. Also, geographically, there were noticeable differences between the countries studied. The results presented should be used to develop strategies and implement policies for sustainable innovative development in the European Union. To the best of the authors' knowledge, this study is a new contribution to assessing the level of innovation potential of European Union member countries and determining the relationship of this potential with selected parameters of the economy of these countries.*

Key words: *Innovation potential; innovation policy; sustainable economic development; Grey Relational Analysis and multidimensional scaling methods.*

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1. Introduction

In view of the dynamic changes taking place in the world, maintaining stable and continuous economic growth is becoming a serious challenge for countries (Cumming & von Cramon-Taubadel, 2018). One of the attributes of competitiveness, and an important factor in their development, is the propensity of the economy to innovative solutions. Innovation affects the pace and direction of economic development of individual countries and companies, as well as social wealth and quality of life, such as through employment and income growth (Atkinson & Ezell, 2014; Chataway et al., 2014). The innovativeness of individual countries, understood as their ability to create innovations, is an evolutionary process, in which the resources of accumulated knowledge and experience related to education and research and development (R&D) activities are very important (Fritsch & Franke, 2004; Kim & Kim, 2022; Un & Rodríguez, 2018). One of the most important factors stimulating the innovation process of economies is also spending on research and development (R&D) activities (Kaur & Singh, 2016), which to a large extent can be regarded as spending on innovation activities (Grzelak et al., 2018). Thus, it can be assumed that R&D activities, like knowledge, play a key role in building an innovative knowledge-based economy (Veselá & Klimová, 2014). This is because this knowledge translates into the creation of innovative techno-logical products and processes, which are a necessary condition for stable and sustainable economic and social development. The innovative activity of countries and their achievements in this regard depend on a number of factors, the most important of which are therefore those related to education and R&D activities.

Therefore, it can be concluded that the prerequisite for the successful innovative development of individual countries and their groups is adequate human capital and an efficient financial sector that invests in R&D activities (Abubakar et al., 2015; Qamruzzaman et al., 2021). The role and importance of human capital stems from its ability to accumulate knowledge and unique skills, which are crucial for the development of new technologies and building a knowledge-based economy. In turn, R&D expenditures provide opportunities to put the potential of human capital into practice. Thus, material re-sources enable more comfortable and also more efficient innovation activities. Most often, countries with high R&D expenditures have a higher level of innovation than those with low expenditures (Pegkas et al., 2019). Thus, human capital and R&D expenditures have a key impact on the development of innovation of individual regions and countries.

The relevance of innovation potential in the context of developing innovation and trying to catch up with the leaders in this process, namely the US and Asian countries, is understood and noticed in the European Union (EU). Since the introduction of the Lisbon Strategy (Lisbon Strategy, 2000), the EU has repeatedly confirmed the importance and commitment to the development of the R&D area as a major factor shaping innovation. This is evidenced by a number of R&D programs, including the EUR 80 billion Horizon 2020 program (Regulation EU No 1291, 2013). By contrast, the budget of Horizon Europe for 2021-2027 is as much as 95.5 billion euros. This makes it currently the most ambitious program regarding the development of research and innovation in the history of the EU.

Its success largely depends on the ability of individual countries to carry out their tasks, i.e., having the resources necessary to absorb and properly use this budget. Therefore, in order for the funds from this program to be used effectively, individual countries, and mainly their companies, should be adequately prepared to implement innovative projects. As in other regions of the world, the human resources responsible for creativity and the generation and adoption of new technologies are crucial in this case. An important factor is also the amount of resources allocated to R&D activities, which largely finance innovation activities. An analysis of the literature indicates that increasing attention is being paid to the study of the innovation of entire economies of individual countries. However, these analyses most often refer to the study of the impact of individual financial factors and innovation potential on the development of the economies of these countries (Ang & Madsen, 2011; Kraftova & Kraft, 2018; Savrul & Incekara, 2015). Few works (Kaneva & Untura, 2018; Lipnik & Bucar, 2017; Szopik-Depczynska et al., 2018), on the other hand, consider both financial factors and people's resources to assess innovation potential. In one paper (Lipnik & Bucar, 2017), the authors determined the efficiency of innovation potential, measured, among other things, by investment in R&D and human resources in selected member states of the EU and the United States, and its impact on the economic performance of these countries. Szopik-Depczyńska et al. (2018), in turn, made a long-term assessment of the effectiveness of action to strengthen innovation within the framework of sustainable development policy in the EU, in which they took into account the importance of financial potential and human resources. By contrast, Kaneva & Untura (2018) determined the impact of R&D and knowledge dissemination, as measured by human resources, on the economic growth of Russian regions.

Thus, these publications refer only in selected aspects to the problem of the innovation potential of individual countries. Thus, a research gap arises, including a more comprehensive approach to this issue, for the EU-27 countries, in a longer perspective (e.g., 10 years), which this work partially fills. In particular, it concerns the assessment of the innovation potential of EU member states, and the determination of its impact on the economy of these countries, characterized by a set of selected indicators.

With regard to the purpose of the conducted research, the following research questions were formulated:

RQ1: What is the level of innovation potential in each of the EU-27 countries and how did it change between 2010-2020 (10-year perspective)?

RQ2: What are the differences in innovation potential between the EU-27 countries?

RQ3: To what extent does the innovation potential of individual countries depend on gross domestic product (GDP) per capita, the number of patents, the overall level of innovation and eco-innovation and their digitalization?

The subject related to assessing the level of innovation potential of EU countries, is crucial primarily due to the fact that there are large economic, social and political differences between these countries, which also has a significant impact on their sustainable development.

In order to answer the questions posed, a research methodology was developed, based on statistical methods of data analysis. Basic descriptive statistics, the Grey Relational Analysis (GRA) approach, being one of the Multiple Criteria Decision Making (MCDM) methods, and multidimensional scaling were used for the study. Since the evaluation of the innovation potential of the EU-27 countries was carried out on the basis of 8 indicators, it becomes a multidimensional problem. Its solution is possible by using MCDM-type methods or factor methods. In the present study, both approaches were used: the Grey Relational Analysis (GRA) approach was used to assess innovation potential, and the multidimensional scaling method was used to determine differences between countries.

In turn, the relationships between innovation potential and gross domestic product (GDP) per capita, the number of patents, the overall level of innovation and eco-innovation of EU-27 Member States and their digitization were checked using non-parametric tests in the form of the Spearman Rank-Order Correlation Coefficient and the Kendall Rank Correlation Coefficient. According to the authors, these methods, fully achieve the research objective.

The basis of the analysis carried out was eight selected indicators characterizing the innovation potential of the EU-27 Member States in the financial and human dimensions.

The originality of the presented research is evidenced by the following factors:

– Filling the existing research gap in the literature, in terms of assessing the level of innovation potential of EU member states as a priority area of innovative development.
– Including in the assessment different but timely and relevant indicators that characterize innovation potential.
– Developing a universal and original approach to evaluating the effectiveness of innovation support policies in the EU-27 countries, allowing for a transparent and broadly comparative assessment of these countries.
– Making an assessment of the effectiveness of the implementation of innovative development policies for all EU-27 countries in a 10-year research perspective, which provides an opportunity to evaluate the economic policies pursued by these countries.
– Developing recommendations on the formation of economic policies of the countries studied in support of the development of innovative capacity.

Thus, the results of the research presented in the paper make it possible to assess the effectiveness of implementing innovative development policies for the EU-27 countries in the long-term to an extent not yet covered in publications.

2. Literature review

The literature review section refers to the most relevant, according to the authors, publications devoted to innovation, methods of its assessment and relating to the role and importance of personnel resources and R&D expenditures on the development of an innovative economy.

2.1. Theoretical background

In the literature, one can see a steadily growing interest in the impact of knowledge, skills and qualifications of workers and R&D financing on economic growth and innovation, and consequently on the competitiveness of the economy of individual countries and companies.

Knowledge of the importance of human capital was established in the 1950s and 1960s, thanks to the work and research conducted by Mincer (1984), Schultz (1961) and Becker (1962). Their studies became the basis for the development of fundamentals regarding the importance of human capital in business and other activity.

Human capital is an economic category, which, in the most general terms, aims to explain the role and significance of personal resources for economic activity and the success or failure achieved in this regard (Becker, 1994; Jagódka & Snarska, 2021; Kucharčíková, 2011). According to Schultz's (1961) theory the acquired competence and knowledge of employees is a form of capital that helps explain why economic growth became so rapid in the 20th century, even though the growth of physical capital, land or labor, did not occur as quickly. He stated that investment in human capital is the main reason for this state of affairs, causing real wages to rise and dynamic economic growth. In turn, Becker (1994) stated that investment in human capital is a form of resource allocation that affects future real income. By investing in human capital, he meant, among other things, education, gaining experience on the job and training (Aghion & Howitt, 1997; Becker, 1962; Fredman, 2014; Grossman & Helpman, 1990; Ober & Kochmańska, 2022).

A number of publications have also extensively recognized the importance of research and development to modern economic growth (Grossman & Helpman, 1994; Guellec & Ralle, 1991).

Thus, it can be concluded that the topics related to determining the role and importance of human capital and R&D expenditures for the development of innovation are important, topical and frequently addressed by researchers. An analysis of the literature indicates that by far more space, in these works, has been devoted to human capital than to the importance of R&D spending. The following sections present a selection of works from both areas considered in the research.

2.2. Human capital and innovation

When referring to human capital, it can be considered from different points of view. On the one hand, as al-ready mentioned, it is knowledge, skills and experience, and on the other hand, it is everything that enables a society to achieve socio-economic well-being (Belenkova et al., 2008; Healy & Côté, 2001; New Sources of Growth, 2013).

It is assumed that highly educated people tend to create more innovations, which support the development of specific industries and lead to increased income and added value (Feldman, 2000). Human capital is therefore important for creating and promoting innovative solutions, and this is true at the enterprise (local) as well as national and regional (group of countries) level (Bianchi, 2001). Research on the human capital and economic growth has also been conducted by many different researchers (Badinger & Tondl, 2003; Diebolt & Hippe, 2022; di Liberto, 2008; Engelbrecht, 2002; Salleh et al. 2022; Sterlacchini, 2008).

Individual human capital also refers to the knowledge of individuals, which is of great importance to many industries and companies. It stems from academic education and vocational training, as well as general management and entrepreneurial experience (Dakhi & de Clercq, 2007). These authors conducted a study for 59 countries and found that countries that had higher levels of individual human capital had more patents (higher fluidity in knowledge creation) and a higher percentage of high-tech exports. This is also supported by the results presented in one paper (Miron et al., 2004), which shows that more creative employees (e.g., engineers and technicians) perform better in terms of innovation, especially when they work in units with a strong culture of innovation. Senior management is also of great importance in this process. Its better preparation regarding strategic leadership improves the innovation performance of these companies and results in better work organization (Helfat & Martin, 2014). Studies published in other works (Grigoriou & Rothaermel, 2014; Liu, 2014) also indicate that companies that have a personnel policy aimed at invention and have leaders in this area in their teams have a significantly higher innovation potential.

Training and improving the competence of employees is also a very important factor in improving company innovation. Ma et al. (2019) conducted a study on human capital in the context of just raising competencies. This research included more than 300 manufacturing companies from 13 countries. The results show that employee training improves the innovativeness of companies in terms of commercial success and the development of new products, as well as the increase in their revenues from the implementation of these solutions. It is also important to note that the impact of training on innovation is greater when companies have a high centralization of power and when they are located in fast-growing economies.

In the process of assessing innovation potential, from the perspective of human capital, the research methods used are also of great importance.

The literature distinguishes various measures for assessing human capital in the context of innovation. These include the average number of years of education of the population aged 25-64 (Bassanini et al., 2001; Bouis et al., 2011) or the share of college graduates in the total population (Ulku, 2004). The results of these studies indicate a statistically significant, strong positive impact of these indicators on economic growth. According to the results presented in one paper (Ulku, 2004), a unit increase in the average number of years of education of the population aged 25-64 translates into an increase of about 4-7% in steady-state GDP per capita. On the other hand, Bouis et al. (2011) point out that the number of years of education is not a sufficiently accurate measure of human capital, as the quality of education is equally important. Thus, when considering these factors, one should also consider the level of education provided in a country.

In summary, it can be said that human capital is of key importance for the development of innovation, both at the enterprise level and at the national and international levels. It is also obvious that human capital is a strong determinant of economic growth, which is confirmed by the results included in another paper (Cuaresma et al., 2014).

Thus, it is fully justified to include this dimension in the process of studying the innovation potential of the EU-27 countries. After all, human capital is of key importance for building an innovative and sustainable economy in the EU.

2.3. Expenditures on R&D and innovation

In addition to human capital, R&D expenditures are another important factor in the development of innovation. Research on this issue focuses on, among other things, explaining the importance of R&D expenditures on the development of an innovative economy (Acs &Audretsch, 1987; Scherer, 1965; Schmookler, 1966). The results presented in these works confirm that R&D expenditures should be considered one of the important factors stimulating the development of innovation. On the other hand, the work of Griliches (1990) also confirmed that these expenditures are a significant predictor of innovation. In turn, Mulas-Granados & Sanz (2008) examined the relationship (convergence) between modern technologies and income in selected regions of EU countries. Using R&D expenditures of all sectors (percentage of GDP) as an indicator of technological contribution, patents per million people (an indicator of productivity) and regional income per capita, they conducted a convergence analysis. The results indicated that the values of indicators related to R&D expenditures and the number of patents coincided with the size of per capita income in the regions studied. Archibugi & Filippetti (2011) conducted a study of the relationship between European member states in terms of innovative capacity over the period between 2004-2008. The results also show a relationship between R&D (research and development) spending and inventiveness (which includes registration of patents, trademarks and utility models). Another paper (Veugelers, 2017) shows that EU countries leading in terms of innovation (above the average level) spend considerably more on R&D (as a share of their GDP) than countries with lower levels of innovation. Such a state of affairs makes it very difficult for these countries to catch up with the existing backlog in this area. The results also showed that the biggest lag is in southern European countries and the new EU-13.

A number of research results, presented in some other works (Bassanini et al., 2001; Bouis et al., 2011) indicate, unequivocally, the significant and positive impact that both the overall volume of expenditures at the national level and in companies on R&B has on economic growth.

The impact of these expenditures on high-tech exports, ICT exports, total exports and economic growth in developing countries in Asia is presented in another paper (Gocer, 2013). The results show that these expenditures resulted in economic growth of about 0.5% and high-tech exports of 6.5%. In turn, some research (Burcu & Ayse, 2014; Guloglu et al., 2012) conducted on developed economies of OECD countries showed that the relationship between R&D spending and innovation and economic growth is both positive and significant.

In general, it can be assumed that R&D expenditures have a very positive impact on economic growth and innovation in the organizations incurring them.

However, there are cases that disrupt this general trend. Well, econometric analyses have shown that government spending on R&D can also have a negative effect on economic growth. Such effects are explained by these expenditures crowding out resources that could be used by the private sector, including in the form of business R&D spending (Guellec & van Pottelsberghe de la Potterie, 2000; Soete et al., 2022). In these cases, however, it should be noted that public R&D spending tends to focus on basic research, often with limited commercialization opportunities, with the result that its effects appear only in the long term, such as in the form of technology diffusion.

Thus, the literature review conducted indicates that the problem of assessing innovation potential is a complex process. On the other hand, it is clear that human capital and R&D spending are crucial for the development of an innovative economy. Especially for the EU, which wants to be one of the leaders of the world economy. There-fore, addressing this topic and including human capital and R&D expenditures in research is fully justified.

3. Material and methods

To assess the level of innovation potential of individual EU-27 countries and analyze their similarities, as well as determine a relationship with the parameters of their economies, a set of relevant indicators and research methods were adopted to achieve this goal. For the research, 8 indicators characterizing innovation potential and 5 characterizing the parameters of EU countries' economies were used. The research was carried out based on the GRA method from the MCDM group of methods, the multidimensional scaling method and two non-parametric tests (Spearman Rank-Order Correlation Coefficient and Kendall Rank Correlation Coefficient). The scheme of the research procedure carried out in the study is shown in Figure 1. The following subsections of the section characterize the indicators and research methods adopted for the study.

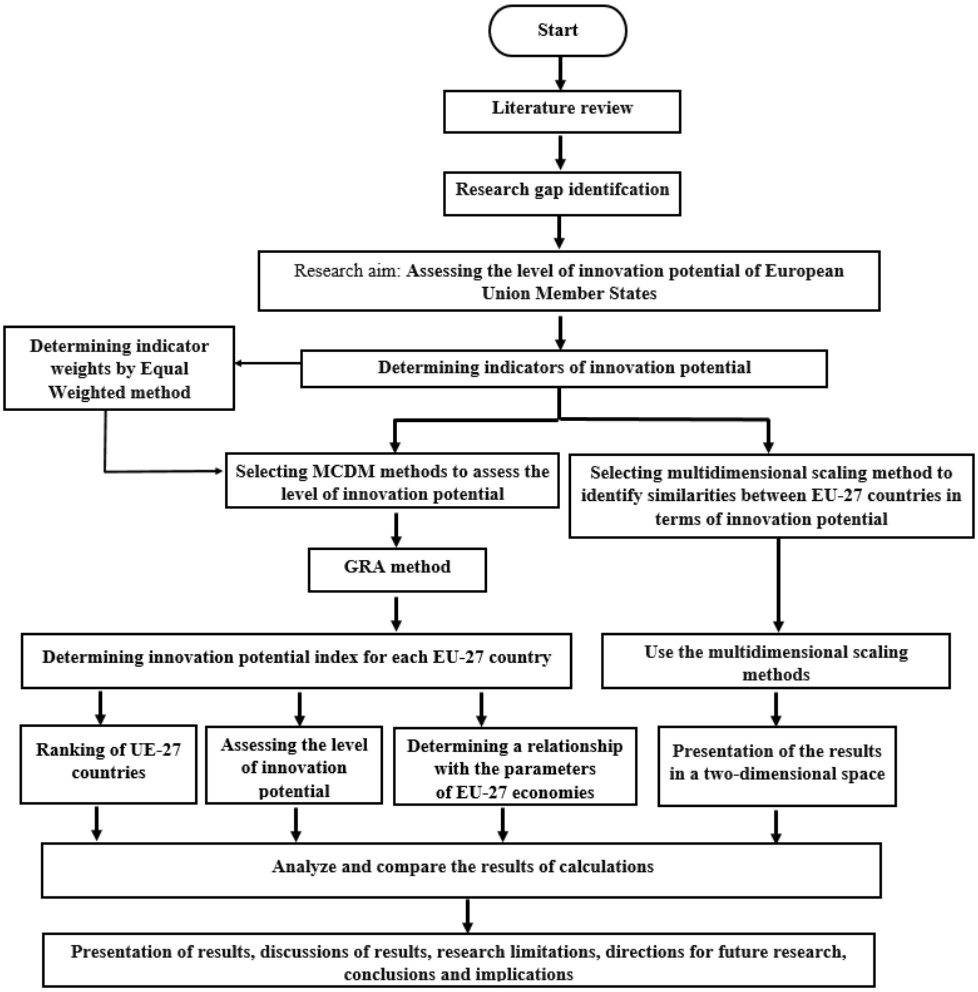


Figure 1. Scheme of the research procedure

3.1. Data

In order to conduct a study aimed at assessing the differences between EU Member States in terms of innovation potential, data from the EUROSTAT database (Eurostat, 2010-2020) were used.

The research used a set of 8 diagnostic variables that characterize the EU countries in terms of innovation potential (Table 1) in financial and human dimensions. The adopted set of indicators included three indicators characterizing the financial potential of the countries studied and five relating to their human capital. The choice of diagnostic variables was the Author's decision, resulting from the analysis of the literature, the authors' own experience and the availability of data. The analysis was conducted for data from 2010-2020.

All diagnostic variables used for the study are characterized by:

– adequacy to the analyzed phenomenon,
– logicality of the interrelationships,
– quantitative nature,
– availability, completeness and timeliness of data.

Table 1. Applied variables for the research

Indicator	Dimensions	Designation
R&D expenditure by business enterprise sector, Euro per inhabitant	Financial potential	X1
R&D expenditure by higher education sector, Euro per inhabitant		X2
R&D expenditure by government sector, Euro per inhabitant		X3
Share of R&D personnel and researchers in total active population and employment, % of population in the labour force - numerator in full-time equivalent	Human capital	X4
Share of people with tertiary education 25-64, %		X5
Graduates at doctoral level, in science, math, computing, engineering, manufacturing, construction, per 1000 of population aged 25-34		X6
Employment in high- and medium-high technology manufacturing sectors, % of total employment		X7
Employment in knowledge-intensive service sectors, % of total employment		X8

The indicators adopted for the study are treated as diagnostic variables. Of primary importance in assessing innovation potential are R&D expenditures, which enable the creation of new knowledge, patents and the implementation of innovations, and the human factor, manifested, among other things, in the share of personnel involved in R&D activities, the number of people with higher education or the number of doctorates and employment in the knowledge-intensive service sector. The two dimensions included in the research (financial and human capital) are complementary and interpenetrate each other, which is obvious. Indeed, the lack of financing will limit research processes and the development of the economy, as will the lack of appropriately qualified personnel. Therefore, it can be concluded that a prerequisite for the development of innovation is the simultaneous possession and allocation by a country of adequate financial resources for research and development, and the possession of adequate human resources for their effective use.

3.2. Methods

The Grey relational analysis method from the MCDM group of methods, the multidimensional scaling method and two non-parametric tests, Spearman Rank-Order Correlation Coefficient and Kendall Rank Correlation Coefficient, were used to conduct the main study.

The selection of an appropriate MCDM-type research method is always a complex problem due to their significant number and widespread use in various types of research (Anselmo Alvarez et al., 2021). Thus, the most commonly used methods for solving multi-criteria problems include: Analytic Hierarchy Process (AHP) (Saaty, 1980), COmbinative Distance-based ASsessment (CODAS) (Keshavarz et al., 2016), Combined Compromise Solution (CoCoSo) (Yazdan et al., 2019), Compressed

PRoportional ASsessment (COPRAS) (Tutak et al., 2021; Zhu et al., 2020), Evaluation based on Distance from Average Solution (EDAS) (Keshavarz et al., 2015), ELimination Et Choice Translating Reality (ELECTRE) (Roy, 1968), Grey Relational Analysis (GRA) (Deng, 1989), Multi-Objective Optimization method by Ratio Analysis (MOORA) (Brauers & Zavadskas, 2006), Simple Additive Weighting (SAW) (Pranolo & Widyastuti 2014), Step-wise Weight Assessment Ratio Analysis (SWARA) (Keršulienė & Turskis, 2011), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) (Behzadian et al., 2012), Preference Ranking Organization METHod for Enrichment of Evaluations (PROMETHEE) (Brans et al., 1984), Višekriterijumsko KOmpromisno Rangiranje (VIKOR) (Opricovic & Tzeng, 2004), and Weighted Aggregates Sum Product ASsessment (WASPAS) (Zavadskas et al., 2013). Methods that are less well known but also increasingly used for multi-criteria studies include: Multi-Attributive Ideal-Real Comparative Analysis (MAIRCA) (Pamucar et al., 2014), Multi-Attributive Border Approximation area Comparison (MABAC) (Pamucar & Cirovic, 2015) and Measurement of Alternatives and Ranking according to COmpromise Solution (MARCOS) (Stevic et al., 2020).

These methods are valuable analytical tools that support the decision-making process under different scales of uncertainty. Considering the multiplicity of developed and applied methods, the GRA method was used for the present study. This method is derived from gray systems theory and allows generating, searching, finding and extracting additional, previously undisclosed, important information on the basis of only partially known information. This is the phenomenon we are dealing with in the presented analysis. At the same time, so far it has not been used to study the problem of assessing the innovativeness of a group of countries, so it provides an opportunity to obtain new interesting results that should enrich the knowledge in the studied area.

3.2.1. The Grey Relational Analysis method

The Grey Relational Analysis (GRA) method based on the gray theory was introduced to make decisions in situations of imprecise and incomplete information (Andrew, 2011; Badi & Pamucar, 2020; Deng, 1989; Siwiec et al., 2022; Wei, 2010). Therefore, data analysis in this method makes it possible to determine the relevance of the characteristics under study, which, combined with the weights determined for them, helps to determine a sequence of relevance that indicates those characteristics that have the greatest impact on the phenomenon under study. Since Gray systems theory allows generating, searching, finding and extracting additional, previously undisclosed, important information on the basis of only partially known information, it makes it possible to model and monitor the behavior of real systems, as well as to describe the rules governing their changes (Gerus-Gościewska & Gościewski, 2022).

The steps in calculating for the GRA method are following:

1) To make a new decision matrix:

$$X = \left[x_{ij}\right]_{m\times n} = \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix} \tag{1}$$

2) To construct normalize the decision matrix:

$$X_{ij}^{*} = \frac{X_{ij} - min\left(X_{ij,} i=1,2,\ldots,m\right)}{max\left(X_{ij,} i=1,2,\ldots,m\right) - min\left(X_{ij,} i=1,2,\ldots,m\right)} \tag{2}$$

$$X_{ij}^{*} = \frac{max(X_{ij,}i=1,2,\ldots,m)-X_{ij}}{max(X_{ij,}i=1,2,\ldots,m)-min(X_{ij,}i=1,2,\ldots,m)} \quad (3)$$

where: X_{ij}^{*} represents the normalized data of each alternative.

3) To determine a gray relational coefficient from equations (4) and (5):

$$\Delta_{ij} = \left|X_{ij}^{*} - X_{oj}\right| \; for \; i = 1,2 \ldots, m \; and \; j = 1,2 \ldots, n \quad (4)$$

$$\gamma\left(X_{oj}, X_{ij}^{*}\right) = \frac{min(\Delta_{ij},i=1,2,\ldots,m;j=1,2,\ldots,n)+\varsigma max(\Delta_{ij},i=1,2,\ldots,m;j=1,2,\ldots,n)}{\Delta_{ij}+\varsigma max(\Delta_{ij},i=1,2,\ldots,m;j=1,2,\ldots,n)} \quad (5)$$

where: $\gamma\left(X_{oj}, X_{ij}^{*}\right)$ is the grey relational coefficient of alternative, X_{oj} is the reference sequence for criterion Cj; and ς is the identification coefficient.

4) To determine of the identification coefficient (most often set as 0.5 (Wei, 2010):

$$\Gamma(X_i) = \sum_{j=1}^{n} W_i \gamma\left(X_{oj}, X_{ij}^{*}\right) \quad (6)$$

where: $\Gamma(X_i)$ is the grey relational grade, and W_i is the weight of *i-th* criterion.

5) To order the alternatives according to the value of the identification coefficient (from the largest to the smallest).

The presented course of action was used to assess the level of innovation potential of individual EU-27 Member States.

3.2.2. Multidimensional scaling

The purpose of multidimensional scaling is to graphically present the structure of similarity between the analyzed countries based on a specific set of diagnostic variables. The graphical representation of the results usually takes the form of a two-dimensional, and less often a three-dimensional map (Tenreiro Machado et al., 2011).

The distance between points is determined from the Euclidean distance (Eq. 7):

$$d_{ij} = \sqrt{\left(X_{i1} - X_{j1}\right)^2 + \left(X_{i2} - X_{j2}\right)^2 + \cdots + \left(X_{ir} - X_{jr}\right)^2} \quad (7)$$

3.2. 3. The Spearman Rank-Order Correlation Coefficient and the Kendall Rank Correlation Coefficient

Two non-parametric tests, such as the Spearman Rank-Order Correlation Coefficient and the Kendall Rank Correlation Coefficient were used to answer the third research question (RQ3). Using these two nonparametric tests, the relationship was measured between a country's innovation potential and the number of patent applications, innovation measured by the Innovation index value, eco-innovation measured by the eco-innovation index value and digitalization measured by the Digital Economy and Society Index value.

The value of Spearman's rank correlation coefficient is determined from equation (8):

$$r = 1 - \frac{6\sum_{i=1}^{n} d_i^2}{n(n^2-1)} \quad (8)$$

where: r is Spearman rank correlation, d_i is the difference between the ranks of each observation, n is the number of observations.

The Kendall coefficient τ is defined according to following equation (9):

$$\tau = \frac{(\#numbers\ concrdant\ pairs - \#numbers\ disconcrdant\ pairs)}{\binom{n}{2}} \quad (9)$$

where: $\binom{n}{2}$ is the binomial coefficient for the number of ways to choose two items from n items and is determine from equation (10):

$$\binom{n}{2} = \frac{n(n-1)}{2} \quad (10)$$

4. Results

4.1. Preliminary analysis

Before the main comparative study of EU member states in terms of their innovation potential, an analysis of the dynamics of change in the values of the diagnostic variables adopted for the research was performed. The results obtained for individual countries are shown in Table 2, and in Figure 2.

Table 2. Indices of the dynamics of change for indicators characterizing the innovative potential of EU-27 countries (2010=100%)

Countries	Diagnostic variables							
	X1	**X2**	**X3**	**X4**	**X5**	**X6**	**X7**	**X8**
Belgium	216%	148%	211%	166%	122%	113%	83%	109%
Bulgaria	348%	135%	180%	167%	130%	75%	130%	140%
Czechia	212%	216%	158%	154%	152%	88%	121%	119%
Denmark	115%	150%	176%	106%	123%	77%	94%	106%
Germany	149%	149%	148%	128%	120%	92%	104%	126%
Estonia	227%	183%	193%	123%	117%	86%	123%	165%
Ireland	170%	134%	119%	158%	126%	111%	82%	119%
Greece	223%	166%	174%	171%	136%	125%	113%	135%
Spain	115%	100%	92%	108%	127%	100%	105%	115%
France	126%	112%	102%	118%	135%	73%	85%	118%
Croatia	215%	226%	144%	152%	140%	80%	116%	156%
Italy	145%	106%	125%	155%	138%	86%	110%	118%
Cyprus	498%	140%	67%	158%	125%	200%	150%	145%
Latvia	178%	267%	174%	131%	147%	50%	169%	125%
Lithuania	476%	203%	260%	123%	144%	80%	144%	174%
Luxembourg	78%	171%	109%	84%	135%	175%	70%	105%
Hungary	255%	130%	107%	173%	138%	100%	117%	124%
Malta	183%	173%	31%	106%	198%	200%	77%	116%
Netherlands	225%	108%	76%	153%	132%	86%	112%	110%
Austria	143%	125%	197%	128%	193%	100%	120%	111%
Poland	660%	263%	15%	212%	149%	100%	117%	126%
Portugal	149%	118%	84%	143%	183%	88%	118%	157%
Romania	290%	67%	163%	124%	136%	29%	143%	167%

Countries	Diagnostic variables							
	X1	X2	X3	X4	X5	X6	X7	X8
Slovenia	143%	116%	100%	122%	156%	41%	121%	137%
Slovakia	256%	189%	131%	124%	158%	60%	130%	139%
Finland	93%	116%	79%	95%	126%	92%	93%	112%
Sweden	134%	112%	115%	112%	136%	71%	89%	119%

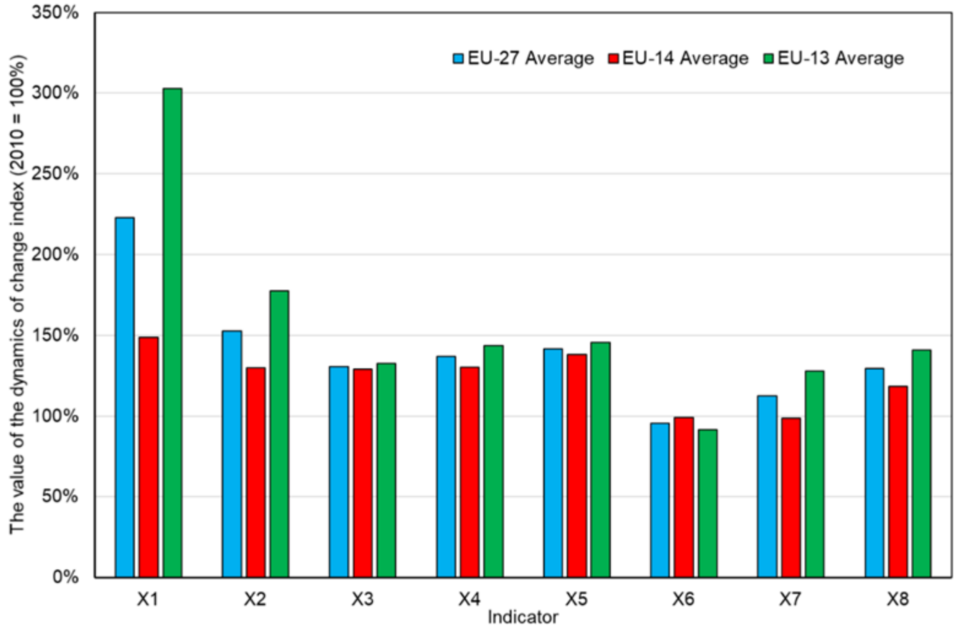


Figure 2. Index values of the dynamics of change for indicators adopted for the study

A comparison of R&D expenditures in individual countries reveals differences between them (Fig. 1; Table 1). In general, the countries which joined the community after 2004, i.e., the countries of the EU-13 (Bulgaria, Czechia, Estonia, Croatia, Cyprus, Latvia, Lithuania, Hungary, Malta, Poland, Romania, Slovakia, Slovenia) in percentage terms, significantly increased their R&D expenditures per capita. The largest increase was reported for the indicator of total R&D expenditure by business enterprise sector (X1), which for this group of countries increased on aver-age by about 303% compared to the base year (2010). The clear leader in this group is Poland (up 660%). The decrease in outlays was found only for Luxembourg (-22%).

In the case of the indicator of R&D expenditure (by higher education sector (Euro per inhabitant) (X2), also by far greater increases were recorded in the EU-13 countries than in the EU-14 (Fig. 2). The only country with a decrease in these expenditures was found to be Romania (-33%).

It is also worth noting the dynamics of change for the indicator of employment in knowledge-intensive service sectors (X8). This is the only indicator that in all countries increased in value compared to the base year, which means that this sector developed dynamically during the period under review. In this regard, the countries in which the value of this indicator increased the most are Lithuania (+74%), Romania (+67%) and Estonia (+65), i.e., countries in the EU-13 group. This group of countries recorded a greater increase than the EU-14 countries.

When analyzing the results, it can also be noted that in most of the EU-27 countries, the number of people aged 25-34 who obtained doctoral degrees in science, mathematics, computing, engineering, manufacturing, construction decreased significantly during the period under review. During the period, 17 countries saw a decrease and the remaining 10 countries saw an increase in the rate of graduates at doctoral level, per 1000 of population aged 25-34 (X6) (Table 2). Romania recorded the largest decrease (-71%). By contrast, the largest increases were reported in Malta and Cyprus (+100%), the two smallest countries in the EU-27. When comparing the EU-14 and EU-13 countries (Figure 2), it can be seen that the more intense decrease in doctorates obtained occurred in the EU-13 countries (-9%).

It should also be emphasized that the index of dynamics of change was determined between the years 2010 and 2020, which means that the final year was a pandemic year. In that year, the effects of the crisis associated with the spread of the SARS-CoV-2 virus were already observed. The result of this condition, evident in many countries, was a reduction in R&D funding. This was due to the reallocation of budget resources to fight the pandemic or in employment in high- and medium-high technology manufacturing sector, due to the ongoing lockdown. Nevertheless, apparent trends in the changes in the values of the indicators studied provide ample opportunities for interpretation and inference regarding the effectiveness of the measures taken by individual countries in the development of innovation.

4.2. Measuring the position and evaluating the level of innovation potential of the EU-27 Member States

In order to answer the first two research questions (RQ1 and RQ2), study was carried out to determine the level of innovation potential of the EU-27 Member States.

Based on the indicators adopted, the values of the index of this potential, i.e. the Grey Relational Grade (GRG) value, were defined. This index should be regarded as a measure of the innovative potential of the individual countries studied. Based on its value, the ranking of the EU-27 Member States in terms of their innovation potential in 2010, 2015 and 2020 was also determined. The results of the calculation and the ranking position for each country are presented in Table 3.

Table 3. The innovation potential index for the EU-27 Member States and their ranking position in 2010, 2015 and 2020

Countries	2010		*2015*		2020		(EU-14) / (EU-13)
	GRG	Rank	*GRG*	Rank	*GRG*	Rank	
Belgium	0.0213	8	0.0213	9	0.0253	5	UE-14
Bulgaria	0.0166	24	0.0169	23	0.0169	25	UE-13
Czech Republic	0.0200	12	0.0208	11	0.0216	10	UE-13
Denmark	0.0273	2	0.0281	1	0.0277	1	UE-14
Germany	0.0240	5	0.0239	5	0.0262	4	UE-14
Estonia	0.0189	15	0.0183	15	0.0189	15	UE-13
Ireland	0.0217	7	0.0224	7	0.0237	8	UE-14

Countries	2010		2015		2020		(EU-14) / (EU-13)
	GRG	Rank	GRG	Rank	GRG	Rank	
Greece	0.0169	21	0.0172	21	0.0179	21	UE-14
Spain	0.0192	13	0.0192	14	0.0193	14	UE-14
France	0.0210	10	0.0208	10	0.0213	12	UE-14
Croatia	0.0166	25	0.0166	25	0.0169	24	UE-13
Italy	0.0181	18	0.0179	18	0.0187	17	UE-14
Cyprus	0.0182	17	0.0178	19	0.0183	20	UE-13
Latvia	0.0167	23	0.0168	24	0.0171	23	UE-13
Lithuania	0.0177	19	0.0179	17	0.0187	18	UE-13
Luxembourg	0.0265	3	0.0248	3	0.0253	6	UE-14
Hungary	0.0183	16	0.0181	16	0.0188	16	UE-13
Malta	0.0165	27	0.0165	27	0.0167	26	UE-13
Netherlands	0.0204	11	0.0204	12	0.0216	11	UE-14
Austria	0.0211	9	0.0225	6	0.0238	7	UE-14
Poland	0.0169	22	0.0171	22	0.0175	22	UE-13
Portugal	0.0174	20	0.0175	20	0.0184	19	UE-14
Romania	0.0166	26	0.0165	26	0.0163	27	UE-13
Slovenia	0.0228	6	0.0222	8	0.0216	9	UE-13
Slovakia	0.0191	14	0.0196	13	0.0198	13	UE-13
Finland	0.0279	1	0.0247	4	0.0266	2	UE-14
Sweden	0.0259	4	0.0272	2	0.0264	3	UE-14

Between 2010 and 2020, the values of the innovation potential index (GRG index) for most EU member states increased. The exceptions are Luxembourg, Romania, Slovenia and Finland, for which the values decreased. The group of countries that were characterized by a slight decrease in the value of this index between 2010 and 2015 include: Germany, Estonia, France, Italy, Cyprus, Luxembourg, Hungary, Romania, Slovenia, and Finland. On the other hand, the countries that were characterized by a decrease in the value of the innovation potential index be-tween 2015 and 2020 are Denmark, Romania, Slovenia, and Sweden. This is a slight decrease in the value of this index, which can be explained as a temporary reduction in the level of innovation potential. In general, however, there was an improvement in innovation potential for the vast majority of EU countries.

The calculations also reveal that during the analyzed period the countries' positions (determined on the basis of the GRG potential index) in the ranking changed relatively little. The same position throughout the analyzed period was maintained by 4 countries: Estonia (15), Hungary (16), Greece (21), and Poland (22). The leader of the innovation potential ranking in 2010 was Finland, and between 2015-2020 Denmark (in 2010 it was the runner-up). The lowest value of the innovation potential index, and therefore the worst ranking, was gained by Malta between 2010-2015, and Romania in 2020.

Based on the calculated value of the innovation potential index (GRG), the level of innovation potential of the EU-27 Member States was assessed:

High level of Innovation Potential

$$GRG \geq \overline{GRG} + s_{GRG} \quad (11)$$

Medium-high level of Innovation Potential

$$\overline{GRG} + s_{GRG} > GRG \geq \overline{GRG} \quad (12)$$

Medium-low level of Innovation Potential

$$\overline{GRG} > GRG \geq \overline{GRg} - s_{GRG} \quad (13)$$

Low level of Innovation Potential

$$GRG < \overline{GRG} - s_{GRG} \quad (14)$$

where: GRG is the innovation potential index, $\overline{GRG}$ is the mean value of the innovation potential index and s_{GRG} is the standard deviation from the mean value of *the* innovation potential index.

Based on the results, the studied countries were divided into four typological groups, which are presented in Figure 3. When analyzing the results (Fig. 3), it can be concluded that throughout the analyzed period, the highest level of innovation potential was characterized by 5 EU countries: Finland, Sweden, Luxembourg, Denmark, and Germany. In addition, Belgium, which was characterized by a medium-high level in 2010 and 2015, also reached a high level in 2020. All these countries are included in the so-called old EU-14. In addition, these countries are among the most economically developed countries of the EU (Cieślik & Wciślik, 2020) which, as can be seen, also translates into the high level of innovation potential achieved by them.

In 2010, none of the countries was categorized as having a low level of innovation potential, while in 2015 such a level was characterized by Croatia, Malta and Romania, and in 2020 additionally by Bulgaria and Latvia. This means that these countries are not keeping up with the pace of development in relation to the rest of the EU. In addition, they all belong to the new EU-13 countries. On the other hand, the low level of innovation was characterized only by countries included in the so-called new EU-13, namely Bulgaria, Poland and Romania, (2013-2020) and Latvia (2014, 2016-2020). It is important to note that the compositions of the taxonomic groups, due to the level of innovation in the analyzed period changed little.

The results presented show that the countries of northern and western Europe are characterized by significantly higher innovation potential than southern and eastern countries.

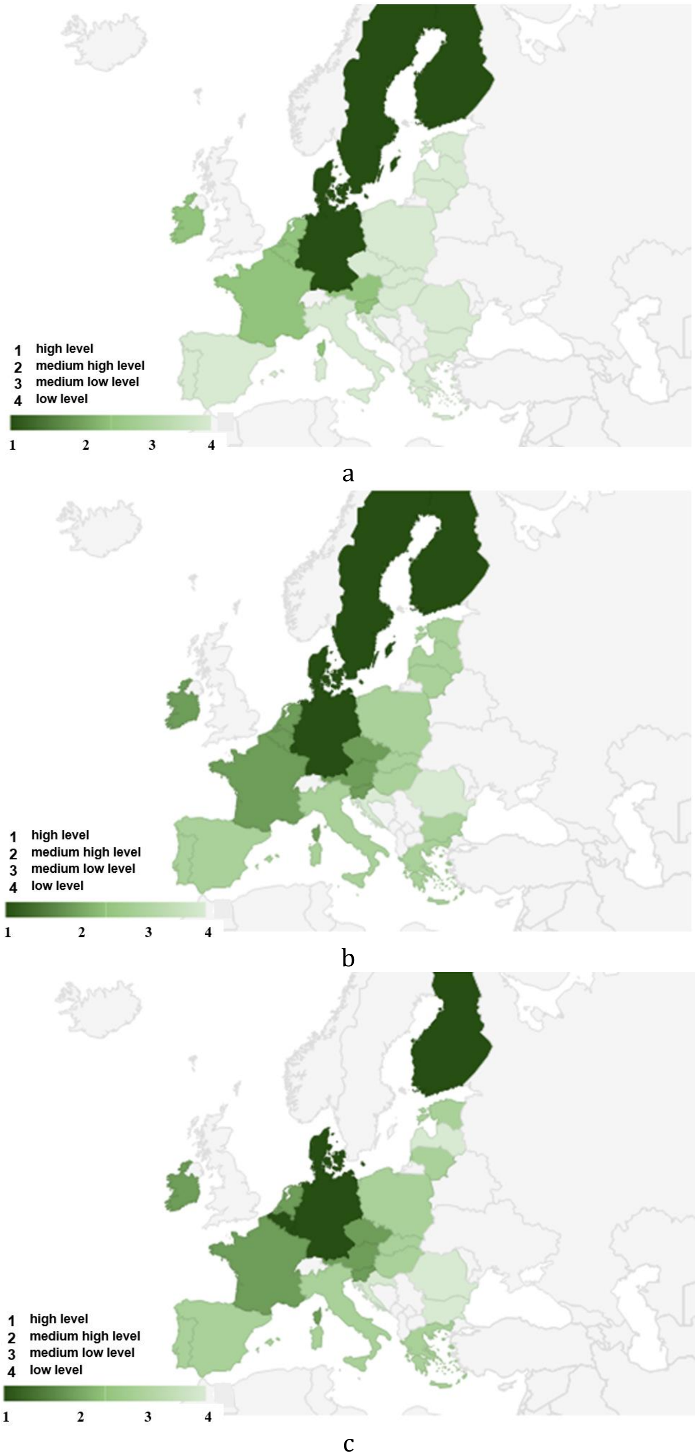
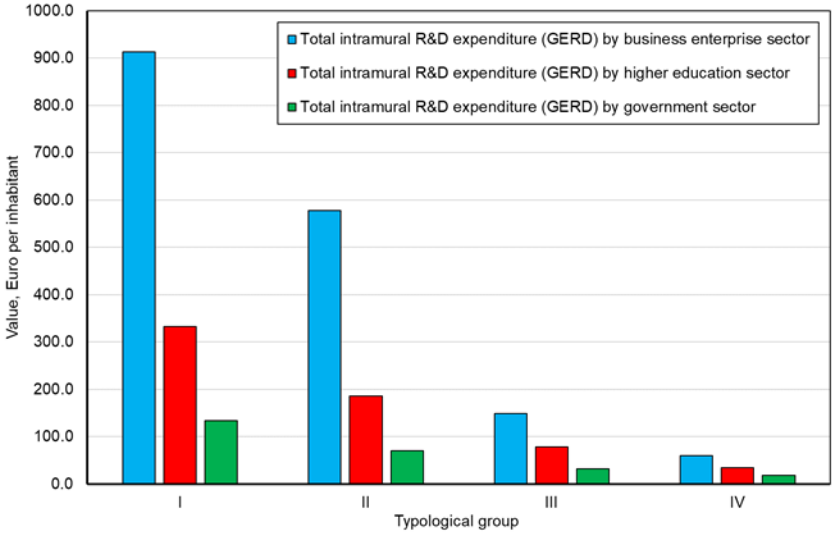
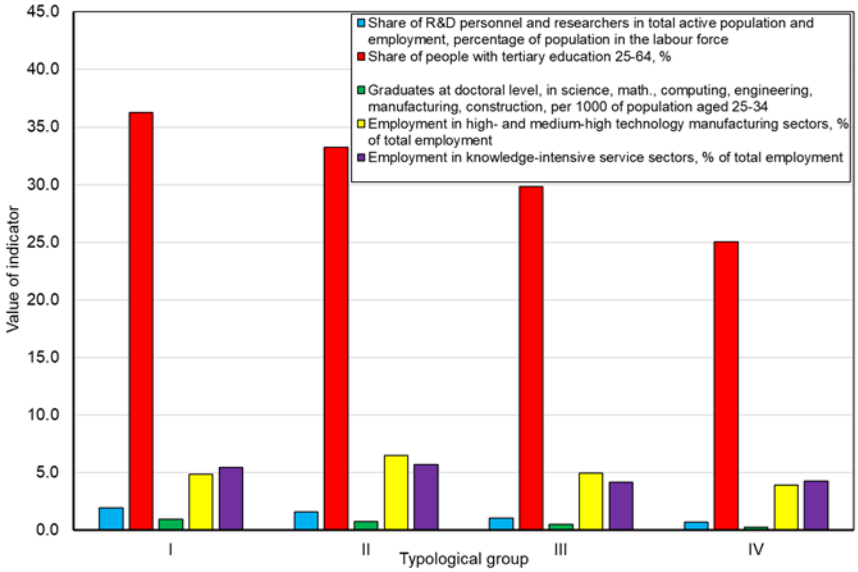


Figure 3. Groups of EU-27 countries by levels of innovation potential in 2010 (a), in 2015 (b) and in 2020 (c)

In order to show differences in typological groups in terms of the values of individual indicators of innovation potential, their average values for 2020 were calculated (Figure 4).



a



b

Figure 4. Average values of individual indicators characterizing innovation potential in typological groups for 2020

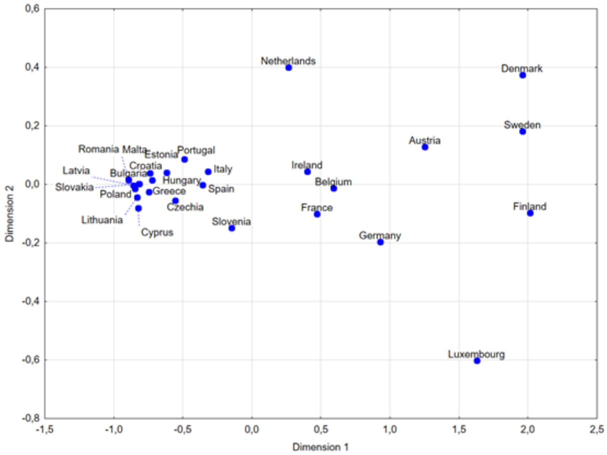
Countries in the first typological group (Belgium, Denmark, Germany, Luxembourg, Finland, Sweden) allocate by far the largest resources to research and development. In this regard, the private sector dominates, with expenditures averaging more than 900 euros per person, nearly 40% more than in the second group, with a medium-high level of innovation potential, and many times more than in the other two groups (Fig. 4a). In terms of higher education sector spending, R&D

spending is significantly lower in each group; even in countries in the first typological group, it is only a little over 300 euros per capita, more than 2.5 times less than private sector spending (Fig. 3a). In the government sector, spending is the lowest, just over 130 euros per capita for the first typological group, and in the fourth group (Bulgaria, Croatia, Latvia, Malta, Romania), just a little over 17 euros per capita (Fig. 4a).

It should also be noted that countries in the first typological group perform slightly worse than those in the second group on two variables: Employment in high- and medium-high technology manufacturing sectors and Employment in knowledge-intensive service sector (Fig. 4b) .

Next, a multidimensional scaling method was also adopted to graphically illustrate similarities between the EU-27 Member States in innovation potential, characterized by a set of 8 diagnostic variables (Fig. 5).

The quality of the fit was determined using the STRESS function (Table 4). The values of STRESS function were: for 2010 – 0.005, for 2015 – 0.011, and for 2020 – 0.013.



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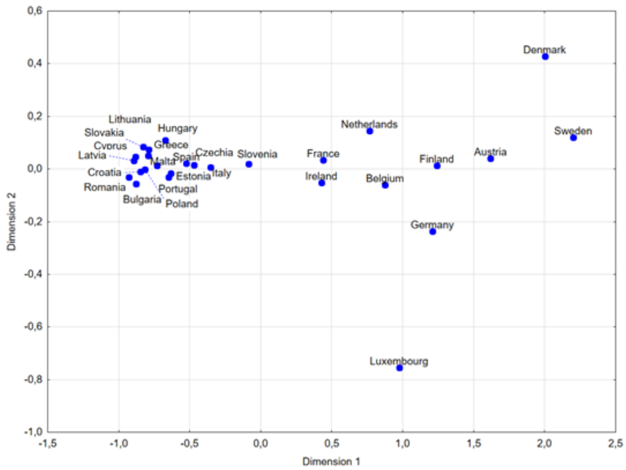

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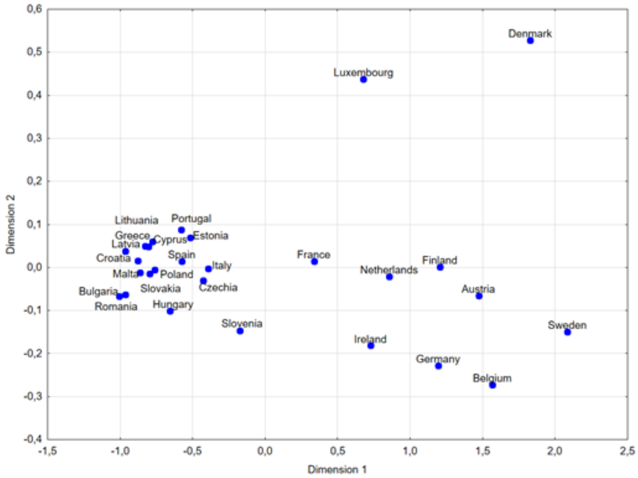

c

Figure 5. Innovation potential of EU-27 member states in two-dimensional space for 2010 (a), 2015 (b) and 2020 (c)

Table 4. The STRESS function value

Year	STRESS
2010	0.005
2015	0.011
2020	0.013

The results of scaling show a significant variation in distance among a large group of EU countries in all analyzed years (Fig. 5.). The greatest similarity with respect to each other is shown by those countries located closest to each other in two-dimensional space, namely Bulgaria, Romania, Slovakia, Czechia, Italy, Spain, Cyprus, Estonia, Portugal, Croatia, Latvia, Malta, Poland, Greece, and Lithuania. Slovakia, too, is close to this group of countries, but there was a noticeable increase in distance from them in 2020. Countries that, on the other hand, show a high degree of variation, characterized by the distance between countries in two-dimensional space, include Denmark, France, Belgium, Sweden, Ireland, Germany, Sweden, Austria, the Netherlands, and Luxembourg.

In the final stage of the research, in order to answer the third research question (RQ3), an analysis was con-ducted to determine the relationship between the innovation potential of the countries studied and GDP per capita, innovation, eco-innovation, digitalization and the number of patents per million inhabitants. These relationships were determined using Spearman Rank-Order Correlation Coefficient and Kendall Rank Correlation Coefficient, and the results are shown in Table 5.

Table 5. Spearman rank and Tau Kendall's correlations between innovation potential and selected parameters in EU-27 countries

Parameters	Spearman rank	Sig (*p*-Value)	TAU KEN	Sig (*p*-Value)
Innovation potential (GRG index) & GDP per capita	**0.814**	**0.000**	**0.639**	**0.000**
Innovation potential (GRG index) & Innovation	**0.838**	**0.000**	**0.681**	**0.000**
Potencjał innowacyjny (GRG index) & Eco-innovation	**0.802**	**0.000**	**0.601**	**0.000**
Innovation potential (GRG index) & Number of patent, per 100 000 inhabitant	**0.808**	**0.000**	**0.635**	**0.000**
Innovation potential (GRG index) & DESI	**0.612**	**0.001**	**0.491**	**0.000**

The results show statistically significant correlations between GDP per capita, innovation potential and in-novation, eco-innovation, number of patent applications and digitalization. The determined coefficients take positive values, which distinguishes a positive relationship between the studied quantities. The values are slightly higher for both non-parametric tests.

The results indicate that innovation potential is closely related to economic development, which manifests it-self not only in the form of GDP per capita value, but also in the form of innovation, eco-innovation or the number of patent applications, which should be considered a positive and necessary factor for the development of the EU as a whole.

5. Discussion

Assessing the innovative potential of EU countries is a topical issue and extremely important for the development of the region. This great importance of innovation in its broadest sense is primarily due to the current direction of the global economy, which must take into account social and environmental aspects in addition to economic ones. Sustainable economic development can only be realized in an innovative knowledge-based economy (Melnikas, 2010; Phale et al., 2021; Ulewicz et al., 2021). Therefore, addressing this topic becomes a fully legitimate and necessary action for the further integration and development of the EU-27 countries.

The paper focuses on an important element of the process of building an innovative economy, which is the assessment of the innovative potential in the group of 27 countries that make up the European community and the determination of the relationship of this potential with economic development. The inclusion in the study of indicators that characterize the most important dimensions related to the implementation of innovation, namely human resources and financial potential in a 10-year perspective provides great opportunities for an objective assessment of the state of individual countries and their efforts in this area.

The results obtained confirm these capabilities, and also allow, to a large extent, the formulation of answers to the research questions posed. They show that in terms of the level of innovation potential in the individual EU-27 countries, there were significant disparities, which persisted throughout the period under study and worsened in several countries.

The results showed that in 2010, none of the EU countries was characterized by a low level of innovation potential, and in the following years – in 2015 and 2020, this level was shown by 3 countries (Croatia, Malta, Romania) and 5 countries (Bulgaria, Croatia, Latvia, Malta, Romania), respectively. This means that the disparity in this regard deepened, especially when it comes to comparing the countries of the so-called "old EU-14" and the "new EU-13." Despite the observed more dynamic growth (in percentage terms) of R&D expenditures in the EU-13 countries, the growth of R&D personnel in the total number of employees or employment in high- and medium-high technology manufacturing sectors and in knowledge-intensive service sectors (Table 3), the results obtained are low.

This shows that despite the EU's pursuit of a common innovation policy, it has not been possible to catch up with all the economic backlog, and in fact there is a deepening of differences between some countries. Undoubtedly, equalization of the level of innovation in the EU-27 is an extremely difficult task, which requires a lot of time and determination of the EU itself and individual countries. Nevertheless, the results indicate that this process is very complex and requires a new approach, especially in relation to the countries of the "new EU-13".

The 'Europe 2020' strategy, which was a supranational, technocratic planning project, set an impressively ambitious strategic goal "to become the most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth" (European Commission, 2010). Unfortunately, achieving this goal, as can be seen from the results of the study, will not be easy, despite the fact that pro-innovation policies are at the forefront of various EU initiatives.

This is confirmed by assumptions about European policy, where innovation is key (Billon et al., 2017; Ober, 2022). Also in the Europe 2020 strategy, special emphasis was placed on R&D, innovation and digitalization. The goal of this strategy was that EU economic growth should be achieved through innovation in the digital environment (Terzić, 2017), which should result in synergies between different EU policies and EU member states (Kordoš, 2016). The European Commission also rightly assumes that without adequate investment in R&D, the EU will lose any chance of being among the world's leaders (Walburn, 2010). The results confirm these assumptions. Unfortunately, the great diversity of EU countries makes it difficult, at this stage, to see the effects of the expected synergies.

On the other hand, it is optimistic that the European innovation leaders, namely Finland, Sweden, Luxembourg, Denmark, and Germany, which was also confirmed in the study (European innovation scoreboard, 2022) and the world (Global Innovation Index, 2022) are the countries in which the threshold of 3% of GDP allocated to R&D has been achieved. These results confirm the huge role of R&D expenditures in the development of an innovative economy.

Among the countries of the "EU-13", the best results in terms of the level of innovation potential were achieved in Slovenia and the Czechia, which is also related to high R&D spending.

The results allow us to conclude that the groups of countries obtaining similar results in terms of the level of innovation potential are concentrated, with a small exception, not only within the groups of countries forming the EU-14 and EU-13, but also geographically.

When analyzing the results, it is worth referring to the findings of the research obtained by Szopik-Depczyńska et al. (2018). However, they did not concern the assessment of innovation potential vs. innovation of EU countries in terms of the implementation of Goal 9 of Agenda 2030, and which was conducted using the author's the composite index. This index uses a measure based on Weber's median vector. The results obtained by these authors reveal that the most innovative countries are Austria, Denmark, Finland, Germany, Luxembourg, and Sweden. By contrast, the present study results indicate that Denmark, Finland, Germany, Luxembourg and Sweden also have the highest innovation potential, while Austria has a slightly lower potential.

Thus, the results from both methods are similar, which can be taken as confirmation of the validity of the algorithms used and the reliability of these results.

Countries with the best performance in terms of innovation potential (high and medium-high levels), with small exceptions, are concentrated in Northern and Western Europe. By contrast, lower levels of this potential are achieved by countries located in Southern and Eastern Europe. Also, the results of Constantin et al. (2021) show that countries from Northern and Western Europe incur higher R&D expenditures compared to Eastern and Southern countries, leading to a more innovative and sustainable path of their development. Also, Pegkas et al. (2019) in their work proved that there is a relationship between innovation and R&D spending for EU-27 Member States. The results also indicate that there is a positive and significant impact of this spending and higher education on the development of entrepreneurship, society and innovation. These results are consistent with previous studies by Buesa et al. (2010), De Rassenfosse & van Pottelsberghe de la Potterie (2012), and Barra & Zotti (2016), among other authors. However, Corradini et al. (2014) also point out that there is a link between R&D and emission abatement, and that innovation is key to reducing emissions and increasing energy efficiency. These results are also fully consistent with those obtained in this paper regarding the positive relationship between innovation development and ecology and the sustainable economy in general.

In the countries, which are in the groups of high and medium-high innovative potential, also the indicators determining the quality of human capital, measured by the share of the population with higher education, are at a much higher level than in the other groups. The high position in this regard of Denmark, Sweden, Finland, Belgium, Germany, Austria is largely due to the high quality of the higher education system, well-developed cooperation between science and industry and the ability to absorb new technologies. Indeed, the quality of the education system also plays an important role in the process of innovation growth. The education system in countries such as the Cyprus, Czechia, Hungary, Estonia, Spain, Greece, Slovenia, Slovakia, Lithuania, Portugal, Latvia, Croatia, Poland, Bulgaria is unfortunately not conducive to promoting creativity and cooperation skills, nor to building intellectual capital (Dworak et al., 2022). This area is also affected by the types of degrees obtained. It is important to remember that the arts and humanities or most of the social sciences can have much less impact on the development of innovation than fields such as business, IT and engineering sciences (Asteriou & Agiomirgianakis, 2001; Samara et al., 2012). It should also be remembered that a high-quality higher education system is, of course, also directly related to spending on R&D activities. Also, the share of employees in the S&T sector in the total number of employees, which also promotes the development of innovation and competitiveness of the economy is crucial, too. In this regard, the structure of employment needs to be considered, especially in sectors that require advanced knowledge and skills. In the process of shaping an innovative knowledge-based economy and information society, the quality of human capital and the adaptability of the educated workforce to the new conditions and challenges of civilization development are therefore significant.

The research also showed that there is a strong positive and statistically significant relationship between innovation potential and the number of patents, innovation, eco-innovation, digitalization and the level of economic development of countries as measured by GDP per capita (RQ3). This means that innovation potential, which is determined by R&D spending and human capital, enables the emergence of modern knowledge, which in turn can transfer to new products, R&D activities in the economy, resulting in its multifaceted dynamic development in the future (Verba, 2022).

Improving the state of innovation potential, especially for countries in typological group III with a medium-low level and group IV with a low level, requires that the governments of these countries develop and pursue long-term, consistent and active pro-innovation policies. It also requires, as already mentioned, a new targeted EU approach for these countries. Without special programs to equalize the level of innovation in each country, the differences between them can only grow, as the results of the studies show. This therefore calls for the identification, design and implementation of appropriate reforms that will improve the innovation potential within the group of these countries. The primary goal in this regard should be to increase R&D spending and dedicate it to areas of strategic importance. Undoubtedly, such areas today are energy, the environment or the digitalization of the economy.

Countries such as Bulgaria, Romania, Croatia, Malta, Poland should implement multi-year economic plans that prioritize R&D spending and strengthen the role of human capital, including employment in R&D units. These measures should stimulate the development of new technologies and encourage and motivate, e.g., through support systems, to build an innovative economy and knowledge society.

Internal and external actions are needed to achieve these goals. Their governments must understand that R&D activity is a key driver of innovation. Without investment in R&D and human capital, it is impossible to build a globally competitive economy. The EU, on the other hand, needs to spend and target its funds more efficiently and effectively to create sustainable development opportunities for all countries in the community.

6. Conclusions and policy implications

The presented work presents a multi-criteria approach to assessing the level of innovation potential of the EU countries, which consists of financial and human potentials.

The structure of the formulated conclusions, resulting from the conducted research, follow the answers to the research questions posed in the introduction. Thus, the results obtained indicate as follows:

- The member states of the European Community are characterized by considerable variation in the level of innovation potential. Thus, in the EU, there is a group of countries with a high level of this potential, which includes highly developed countries, namely Denmark, Finland, Germany, Luxembourg and Sweden. On the other hand, however, there is a large group of countries with a low level of this potential like Croatia, Malta and Romania between 2015-2020, and Latvia in 2020.
- EU countries are characterized by moderate temporal variation in changes in the level of innovation potential. Few changes in this regard were reported during

the period analyzed. The level was increased only by Belgium (from medium high to high), and decreased by Croatia, Latvia, Malta and Romania (from medium low to low).

- The results show that innovation potential is significantly related to the level of economic development as measured by GDP per capita, innovation, eco-innovation, invention, and digitization.

Innovation potential, the measures of which in this study were human resources and R&D expenditures, is now one of the foundations for the development of countries' economies. Through innovative activity, economic growth occurs, which in turn drives further innovation. If these innovations also involve ecology, environmental protection and energy transition, the benefits multiply. Thus, when investing in this area of state functioning, one should consider a sustainable future, which can contribute to economic development and improve the lives of citizens.

Therefore, taking into account the results of the studies carried out, and in particular the relationship between GDP and innovation potential, of a country, it is reasonable to develop regulations that will determine the minimum level of expenditures on research and development activities in relation to the country's GDP, in order to ensure friendly conditions for the development of innovation. This is because it is difficult to imagine, in the present reality, a modern and competitive economy, of any country of the EU not based on innovative solutions. This issue is well understood in the EU, which is taking increasingly decisive measures to use the potential for innovation to build a sustainable knowledge-based economy.

In this regard, it becomes reasonable, for example, to establish and build innovative cooperation clusters, within which countries with a low level of innovation could benefit from the experience and assistance of those with a much higher level of this development. These and probably a number of other solutions should enable a more balanced and even development of innovation throughout the European Union, which, especially in the context of the energy transition and the current geopolitical situation in Europe, is of great importance for its further development. Broad cooperation and solidarity of all countries should support these processes.

As with many other studies, this one is also characterized by certain limitations, which at the same time can be seen as potential directions for further research. As already mentioned, in this study, innovation potential was characterized by a set of 8 indicators. It seems reasonable to check whether and how a larger number of these indicators would affect the results obtained. It is worth considering expanding the analysis to include new dimensions, such as social and educational, and analyze their impact.

In addition, the study was conducted at the national level, so the indicators adopted refer to individual whole countries. Experience shows that the levels of innovation in the regions of individual countries also show great variation, so a regional analysis (of states, sub-regions, provinces, departments, etc.), as data is available, of course, would probably also be very interesting. Its results would additionally fit into the regional policy of the EU, which is also of great importance for the development of individual countries, their cooperation and improvement of living conditions.

The question of the analytical methods used to study this highly interesting multi-criteria problem also offers considerable prospects. As mentioned earlier, the application of other methods and comparison of their results should also provide a lot of new knowledge of the innovation potential of individual EU countries.

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