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Innovation in the economies of Central and Eastern Europe – long-term benchmarking

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Abstract. Innovation is an important determinant of development that is of particular importance in developing and emerging economies. For this reason, the aim of this research is to analyze innovation in the countries of Central and Eastern Europe from a long-term perspective, covering 2015-2022, and to classify the studied economies taking into account the dynamic approach to the development of innovation. The article uses data from the European Innovation Scoreboard (EIS), descriptive statistics, and cluster analysis as a method of unsupervised learning. The research results indicate the existence of five innovation development paths in the analyzed region: (1) very low average innovativeness, regressive or low rate of innovation change, very large distance to the EU average; (2) low average innovativeness, high pace of innovation changes, large distance to the EU average; (3) medium average innovation, low rate of innovation change, large distance to the EU average; (4) high average innovation, high rate of innovation change, small distance to the EU average; and (5) very high average innovation, low rate of innovation change, zero distance to the EU average.

Keywords: innovative economy, innovation in developing and emerging economies, European Innovation Scoreboard, long-term evaluation of innovation

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1. INTRODUCTION

In modern economies, innovation is a key determinant of civilizational, social and economic development. Therefore, it also affects the level and quality of life in the society and is thus broadly understood as an indicator of well-being. Nevertheless, the ultimately achieved level of innovation is very dependent on the age of macro- and microeconomic factors. It is also the result of the involvement of all enterprises and institutions operating in a given country, in both the private and public sectors. For these reasons, improving and reshaping innovation is an extremely complex and difficult task.

Emerging and developing economies are particularly interested in improving innovation because a high level of innovation helps to reduce the distance to developed economies. Therefore, the literature on the subject often addresses issues related to innovation improvements in less developed regions. The considerations addressed in this article are part of the above trend and refer to the countries of Central and Eastern Europe, a region that is economically lagging behind Western European countries.

The aim of this article is to analyze innovation in the countries of Central and Eastern Europe from a long-term perspective, covering the years 2015-2022, and to classify the studied economies taking into account the dynamic approach to the development of innovation. To achieve this goal, this article begins with a two-thread literature study on the European Innovation Scoreboard (EIS) and the use of this tool in assessing the innovativeness of CEE economies. Then, the research methodology is presented, which includes measures of the dynamic phenomena and clustering as a tool for unsupervised machine learning. The results of the comparative analysis and grouping of the surveyed countries are presented next. The article ends with references to the previous research, conclusions, and suggestions for further research directions.

The results obtained in the article contribute to diagnostic knowledge in the field of innovativeness of developing economies located in Central and Eastern Europe. They also highlight the study of innovation from a long-term perspective, taking into account its initial level, pace of change, and distance to the EU average, and facilitate the classification of the surveyed countries in terms of the chosen innovation development paths.

1. LITERATURE REVIEW

The concept of innovation was introduced and developed in management sciences by J. Schumpeter, who considered the following to be a manifestation of innovative activity:

- Launching a new product;
- Implementation of a new production method;
- Entering a new market;
- Acquiring new raw materials;
- Introducing a new organizational structure in industry (Schumpeter, 1934, 1965).

Nowadays, the scale and scope of the above activities determine the innovativeness of entire economies, significantly affecting their development opportunities (Gouvea *et al.*, 2021; Medase and Wyrwich, 2022; You *et al.*, 2022). For these reasons, the assessment of innovation and its international comparisons on micro and macro scales are considered in many scientific and economic studies (Lema *et al.*, 2022; Guerrero and Urbano, 2021; Dziallas and Blind, 2018; Edison *et al.*, 2013; Hasselbalch, 2018).

Innovation is usually assessed in two dimensions (Nawrocki and Jonek-Kowalska, 2022; Nawrocki and Jonek-Kowalska, 2023):

1. Potential, relating to the possession of resources and competences enabling conducting innovative activity;
2. Effective, concerning the effects of the undertaken innovative activities.

Carrying out parallel assessment in both of these areas, in turn, makes it possible to obtain an answer to the following question: To what extent do the possibilities to create innovations ultimately translate into the real dimension of innovation, the effects of which can be used by the society and the economy?

In the assessment of potential innovation, human resources are most often assessed because they are carriers of entrepreneurship and creativity, which are a prerequisite for developing innovation (Knudsen and Schleimer, 2022; Zhang and Luo, 2020; Kato *et al.*, 2015). Financial resources are also important; in

turn, they determine the phase of implementing innovations. The pool of R&D expenditure also depends on financial resources (Tortorella *et al.*, 2022; Herstad and Sandven, 2020; Kim, 2014). In terms of resources and competencies, the existing resource equipment of the economy and the enterprises operating in it is also important, including, in particular, the possessed know-how, access to modern technologies, as well as to already developed and used patents and licenses (Shuwaikh and Dubocage, 2021).

In the assessment of effective innovation, two dimensions are most often assessed: intellectual and financial. The first concerns patents, licenses, know-how, or new products, services, and technologies (Buchana and Sithole, 2022; Amdaoud *et al.*, 2021; Makkonen and Van der Have, 2013; Freeman and Soete, 2009). The second relates to financial performance, including, in particular, sales revenue, market share, or profit level (Duke *et al.*, 2022; Lee *et al.*, 2020).

The approach to assessing innovation described above is also used in the European Innovation Scoreboard (EIS) discussed in this article (Onea, 2020; Leogrande, 2022). The EIS includes both measures to assess the innovative potential of economies and the results of actions taken to strengthen the innovation (Costantiello *et al.*, 2021; Natário and Couto, 2022; Pavlik *et al.*, 2022). The principles of innovation assessment in EIS are described in detail in the methodological part of this article. A review of the literature relating to research conducted using the results contained in the EIS in the countries of Central and Eastern Europe is presented below.

Thus, the EIS in the region under study is most often used for comparative analysis of developing countries in relation to developed countries and the average for the European Union (EU). This helps to identify areas that need strengthening and improvement. Belanova (2021) (Belanova, 2021) conducts such an analysis for the economy of Slovakia. It showed that the overall innovativeness in this country is rated quite low and, unfortunately, it may deteriorate over time. Slovakia's innovation strengths include the use of information technologies; sales impact; and environmental sustainability. In contrast, the weakest side of the innovativeness of the Slovak economy is considered to be investments and outlays for the development of innovativeness. According to the author of the described research, this is the main reason for the low innovativeness of Slovakia compared to other EU countries.

In turn, Dworak (2020) (Dworak, 2020), in the case of the innovativeness of the Polish economy (assessed based on the EIS), points out that the transfer of modern technologies to Polish enterprises usually takes place in the form of direct investment in the form of inputs for production located abroad. Foreign investors do not create new R&D jobs, which significantly weakens the Polish innovation potential. Without changing the approach in this respect, innovation in Poland will be mainly imitative. It will also be impossible to permanently and significantly increase the competencies and innovative capacity of human resources.

Domadenik et al. (2019) (Domadenik et al., 2019), describing Slovenia's low and weakening position in the EIS, emphasize the importance of R&D expenditures in the development of innovation. The authors note that large Slovenian enterprises willingly and consciously invest several percent of their annual revenues in pro-innovation activities. They also train their staff. Unfortunately, small- and medium-sized enterprises do not take such actions and do not consider them necessary, failing to see the role of innovation in the micro and macroeconomic scale. According to the researchers, this is the main reason for the low and weakening innovativeness of the Slovenian economy.

Nastacă and Nastaseanu (2021) (Nastacă and Nastaseanu, 2021)—based on research into Romania, which has been the weakest in the EIS for many years—state that the Romanian innovation development policy is not effective. The main weakness of this economy is poorly qualified human resources, which are the main driving force of entrepreneurship and creativity. The attractiveness of the research sector is also very bad, which, in turn, translates into both poor interest from investors and a low level of education of staff for enterprises and institutions.

This review shows that EIS-related research is mainly conducted in a country-by-country context. The need to conduct this research is a result of the low assessment of innovation and the need to strengthen it. These considerations are also dictated by the above premise. Nevertheless, they are distinguished from those conducted so far by a broader analytical perspective, covering 11 countries in Central and Eastern Europe, and a dynamic study of the paths of innovation development covering the period of EIS operation, i.e., the years 2015-2020.

2. METHODOLOGICAL APPROACH

The analysis carried out in the article is long-term and covers the years 2015-2022. The article uses the results of innovation contained in the European Innovation Scoreboard (EIS). This is an instrument for assessing and monitoring the innovativeness of the European Union economies, implemented in 2015. It enables the creation of innovation rankings and comparative analysis, both in relation to individual countries, as well as within specific areas and assessment indicators. The final assessment of the innovativeness of EU economies—the so-called *Summary Innovation Index* (SII)—is determined as the arithmetic mean of 32 innovation indicators, which are included in Table 1.

Table 1

Innovation indicators within European Innovation Scoreboard

General thematic area	Specific thematic area	Indicator
1. Framework Conditions	1.1 Human resources 1.2 Attractive research systems 1.3 Digitalization	1.1.1 New doctorate graduates 1.1.2 Population with tertiary education 1.1.3 Population involved in lifelong learning 1.2.1 International scientific co-publications 1.2.2 Scientific publications among the top 10% most cited 1.2.3 Foreign doctorate students as a % of all doctorate students 1.3.1 Broadband penetration 1.3.2 Individuals with above basic overall digital skills
2. Investments	2.1 Finance and support 2.2 Firm investments 2.3 Use of information technologies	2.1.1 R&D expenditure in the public sector 2.1.2 Venture capital expenditures 2.1.3 Direct and indirect government support of business R&D 2.2.1 R&D expenditure in the business sector 2.2.2 Non-R&D innovation expenditures 2.2.3 Innovation expenditures per person employed 2.3.1 Enterprises providing ICT training 2.3.2 Employed ICT specialists
3. Innovation Activities	3.1 Innovators 3.2 Linkages 3.3 Intellectual assets	3.1.1 SMEs introducing product innovations 3.1.2 SMEs introducing business process innovations 3.2.1 Innovative SMEs collaborating with others 3.2.2 Public-private co-publications 3.2.3 Job-to-job mobility of HRST 3.3.1 PCT patent applications 3.3.2 Trademark applications 3.3.3 Design applications
4. Impacts	4.1 Employment impacts 4.2 Sales impacts 4.3 Environmental sustainability	4.1.1 Employment in knowledge-intensive activities 4.1.2 Employment in innovative enterprises 4.2.1 Exports of medium and high technology products 4.2.2 Knowledge-intensive services exports 4.2.3 Sales of new-to-market and new-to-firm innovations 4.3.1 Resource productivity 4.3.2 Air emissions by fine particulates 4.3.3 Environment-related technologies

Source: *EIS*

The long-term innovation analysis was carried out in two stages. In the first, descriptive statistics were used to characterize SII changes. The following were used:

- The SII arithmetic mean to illustrate and compare the overall level of innovation;
- The average annual pace of SII changes to determine the pace of innovation development;
- Relative change of SII in 2022 in relation to 2015 to identify the holistic level of innovation improvement/deterioration;
- The distance between the SII of individual countries and the value of SII in the European Union in 2022 illustrating the scale of differences in the development of innovation.

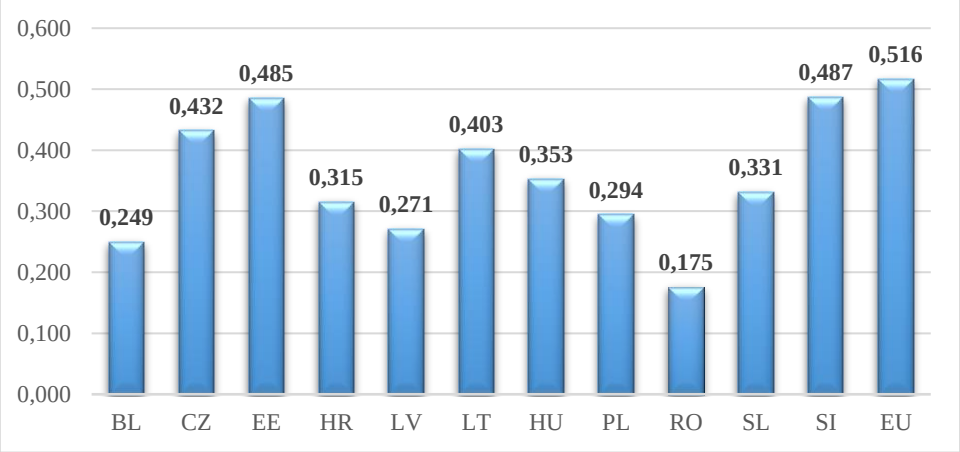
In the second stage, the above parameters were used to classify the surveyed countries in order to identify paths of innovation change. This classification was carried out using cluster analysis, a method of unsupervised learning. Cluster analysis is a tool for exploratory data analysis, the aim of which is to arrange objects into groups in such a way that the degree of linking objects with objects belonging to the same group is as large as possible, and that with objects from other groups is as small as possible. All calculations were performed using the *Statistica* package.

3. CONDUCTING RESEARCH AND RESULTS

As already mentioned, the research used the Summary Innovation Index from 2015-2022 to reflect changes in individual countries' innovation level over time. In order to group the countries, four classification variables were established, described in the previous chapter: the arithmetic mean of the scores obtained, the average rate of change in the SII, the total change in innovation in the analyzed period, and the distance of individual economies to the SII of the European Union in 2022. The following sections present the above parameters and the results of the classification conducted. Detailed SII values obtained in 2015-2022 are presented in the annex to this article.

3.1. Evaluation of innovation changes over time

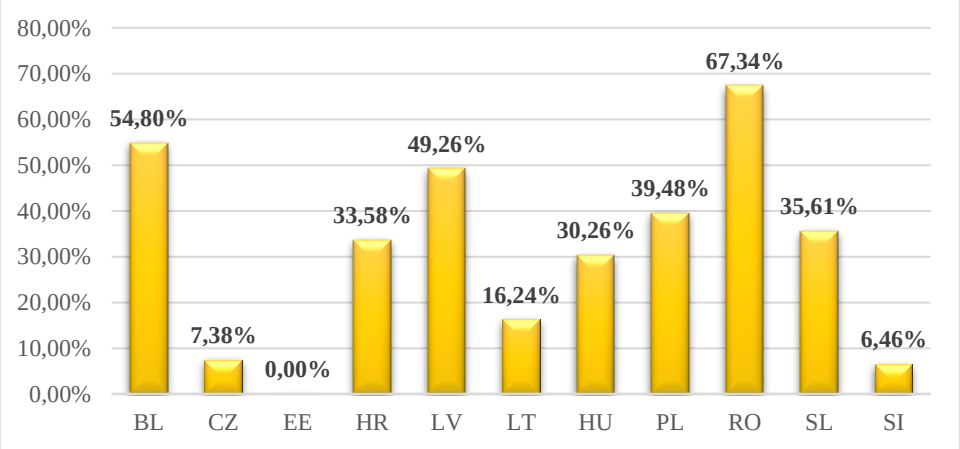
The first of the analyzed parameters was the arithmetic mean SII obtained by individual countries in 2015-2022. This is presented in Graph 1.



Graph 1. The average value of the Summary Innovation Index in 2015-2022
Source: *own calculations based on EIS data*

The data presented in Graph 1 show that none of the countries of Central and Eastern Europe obtained innovation higher than the average for the European Union, which illustrates the difficult situation of this region and its problems catching up with Western developed economies. Nevertheless, four countries managed to come close to the EU average: Slovenia, Estonia, the Czech Republic, and Lithuania. Romania was the worst in the ranking, the only one scoring below 0.200. Poor innovation performance is also shown by Bulgaria, Latvia, and Poland.

Graph 2 shows the distance of the surveyed countries to the average SII value in the European Union and allows us to look at the differences in innovation in relative terms. The data presented in it show that the regional innovation leaders (Slovenia, Estonia, Czech Republic) are separated from the EU average by only a few percent, from 0.00% to 7.38%. These countries are, therefore, most likely to improve their position in the EIS in the future. They also create better conditions for socio-economic development, which are closely related to innovation. The longest distance to the EU average awaits Romania and Bulgaria, where the distance to the EU exceeds 50%. The countries also facing a difficult situation are Poland, Slovakia, and Croatia.



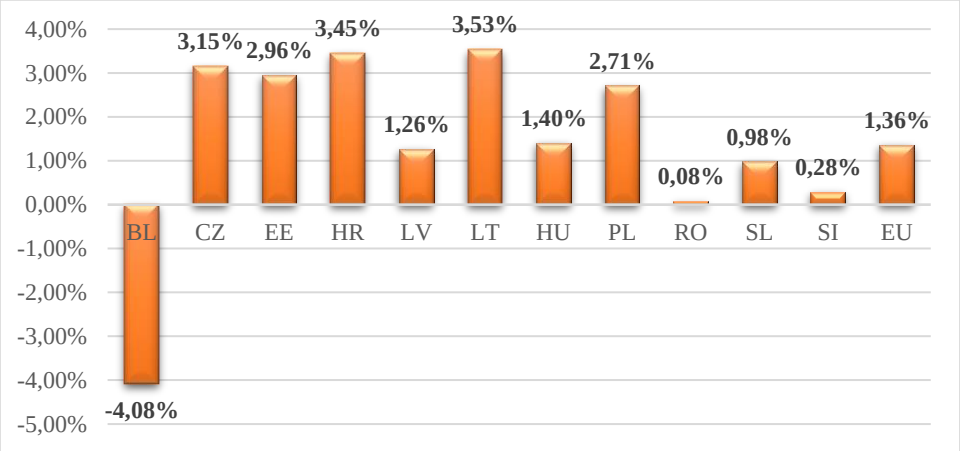
Graph 2. Distance of the surveyed countries to the average SII value in the European Union in 2022

Source: *own calculations based on EIS data*

Bearing in mind the above circumstances, it is worth estimating the pace at which the countries of Central and Eastern Europe improved their innovativeness expressed in SII. Thus, the average annual rate of change in the SII of the surveyed economies is shown in Graph 3. The data presented therein show that the SII in Bulgaria has been systematically deteriorating over time; in Romania, it is characterized by the lowest average annual growth. This means that the countries of the region that are weakest in terms of innovation do not make sufficient efforts to improve their results. It will, therefore, be very difficult for them to match the regional and EU leaders.

In contrast, innovation improved the fastest in Lithuania, Croatia, and the Czech Republic. Lithuania and the Czech Republic translated this dynamic pace of change into high positions in the innovation ranking. Thanks to this, Croatia has a chance to reduce the fairly large distance to the EU average.

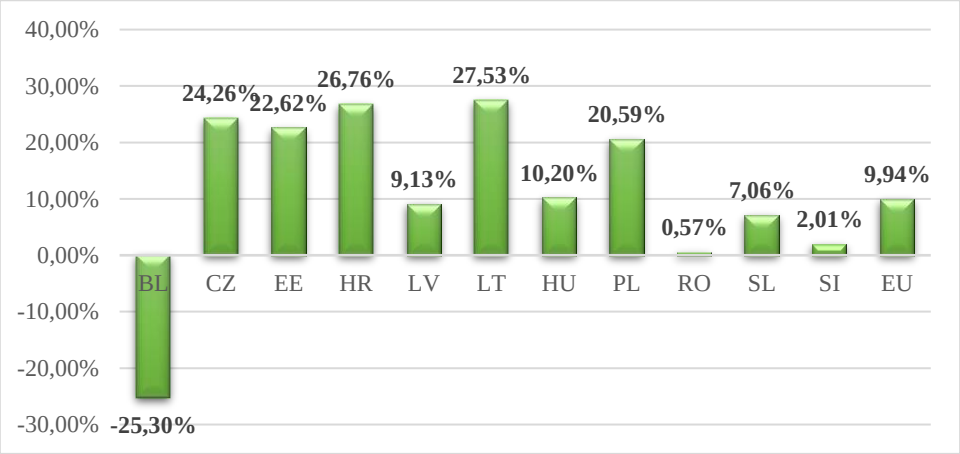
Notably, different strategies for innovation are being developed in Slovenia and Estonia—countries with the highest average SII. In Slovenia, the rate of change of the SII is very low, which proves that the level of innovation has been maintained at a fairly constant level over time. In contrast, in Estonia, the pace of innovation changes is high, which confirms systematic efforts to improve it and bodes well for the future.



Graph 3. The average annual rate of change in the SII of the surveyed Central and Eastern European countries in 2015-2022

Source: *own calculations based on EIS data*

In a dynamic approach, it is also necessary to assess the size of the change in the level of innovation throughout the analyzed period (Graph 4).



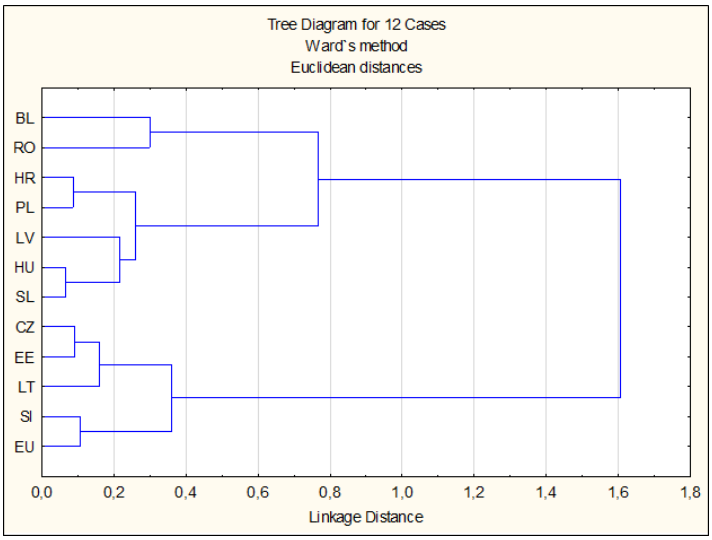
Graph 4. Change in the SII of the surveyed Central and Eastern European countries in 2022 compared to 2015

Source: *own calculations based on EIS data*

Bulgaria is characterized by a regression in innovation, Romania and Slovenia by a very low total value of change over the eight-year analysis period. The highest improvement in innovation was recorded in Lithuania, Croatia, the Czech Republic, Estonia, and Poland. Due to the relatively high SII in 2015, Lithuania, Estonia, and the Czech Republic were among the top countries in Central and Eastern Europe, while Croatia and Poland made an attempt to reduce the distance to the leaders of the region and the European Union.

3.2. Classification of the surveyed countries taking into account the dynamics of changes in innovativeness

In the second research stage, the parameters described in the previous section were used to classify the analyzed countries of Central and Eastern Europe. The results of this stage are presented in Graph 5.



Graph 5. Tree diagram in the assessment of changes in the innovativeness of Central and Eastern European countries

Source: *own calculations based on EIS data*

From the results of the cluster analysis, the following groups can be distinguished:

1. Bulgaria: very low average innovativeness, regression or low rate of innovation change, very large gap to the EU average;
2. Romania: very low average innovativeness, regression of innovation change, very large gap to the EU average;
3. Poland, Croatia, Latvia, Hungary, Slovakia: low average innovativeness, high pace of innovation changes, large gap to the EU average;
4. Czech Republic, Estonia, Lithuania: high average innovativeness, high pace of innovation changes, small distance to the EU average;
5. Slovenia: leader in average innovation, low rate of change in innovation, zero distance to the EU average.

The analysis shows that the countries of Central and Eastern Europe, despite originally belonging to the same groups of innovators in the EIS, differ from each other from a dynamic analytical perspective. The fourth group has the most promise for the development of innovation. Countries that belong to this group have a chance to quickly improve their position in the European ranking. Slovenia, included in the fifth group, is at the top of the ranking, but its low progress in terms of innovation may lower its position in the future.

Groups 2 and 3 are in an average situation. In the second group, the problem is the slow pace of innovation changes. In the third group, the difficulty is the low initial level of innovation. The worst prognosis for the development of innovation concerns the first group, in particular Bulgaria, where SII is systematically deteriorating.

In accordance with the adopted research methodology, in the rest of the article, the analyses are detailed by indicating the strongest and weakest areas of innovation assessment adopted in the EIS. The results of this part of the analysis are presented in Table 2.

Table 2

Strengths and weaknesses of the innovativeness of the surveyed countries based on area assessments in the EIS in 2022

Country	Innovation strengths	Innovation weaknesses
Bulgaria	intellectual assets; sales impacts	finance and support; human resources
Czechia	innovators; information technologies	human resources; digitalization
Estonia	linkages; employment impacts	environmental sustainability; sales impacts
Croatia	innovators; linkages	firm investments; intellectual assets
Latvia	digitalization; information technologies	environmental sustainability; firm investments
Lithuania	innovators; linkages	attractive research systems; sales impacts
Hungary	linkages; finance and support	innovators; human resources
Poland	intellectual assets; digitalization	innovators; attractive research systems
Romania	digitalization; sales impacts	innovators; linkages
Slovakia	sales impacts; information technologies	finance and support; innovators
Slovenia	human resources; linkages	firm investments; finance and support

Source: *own elaboration based on EIS*.

According to the data presented in Table 1, both the strengths and weaknesses of innovation in individual countries are diversified, which proves that there are different ways of creating innovation in general. The most frequent innovation strengths are linkages, which means strengthening (1) cooperation between small- and medium-sized enterprises; (2) publishing cooperation between the private and public sector; and (3) individual mobility of employees. Among the frequently occurring strengths, the following can also be indicated: digitalization, innovators, and information technologies, which proves the dynamic development of IT and telecommunications infrastructure and the competence of human resources related to this infrastructure.

In contrast, the areas that do not appear among the strengths in any of the analyzed Central and Eastern European countries are attractive research systems, firm investments, employment impacts, and environmental sustainability. The listed areas can, therefore, be considered problematic in all countries of the analyzed region. They concern both the intellectual sphere, related to the internationalization and citation of publications, and the financial sphere, related to enterprises' expenditure on innovation. Employment in innovative and knowledge-based companies is also a problem, which is certainly due to the traditional structure of the industry in Central and Eastern Europe. None of the surveyed countries is also strongly committed to sustainable development, which is also typical of this region of Europe. Environmental difficulties result from both the excessive use of traditional energy carriers and the lack of financial resources to allow the implementation of pro-environmental technologies.

Interestingly, the area of innovators also appears, most often, among the weaknesses, which means that not all Central and Eastern European economies manage to activate the sector of small- and medium-sized enterprises to strengthen innovation. Problems are also related to finance and support, which indicates that there is a low level of state financial involvement in the development of innovation. Human resources are also a frequent weakness, assessed in the context of the level of education and lifelong learning.

Among the weaknesses, there are no areas such as information technologies and employment impacts, which may suggest that there are no major problems with access to modern technologies and related competencies.

CONCLUSION

The results of the analyses conducted show that the countries of Central and Eastern Europe struggle with low innovation and there is a large distance to the average for the European Union and developed countries, which confirms previous observations obtained: Belanova, 2021; Dworak, 2020; Domadenik et al., 2019; Nastacă and Nastaseanu, 2021. Nevertheless, the studied economies are not a monolithic group characterized by the same problems and innovation development paths.

It is notable, however, that among the frequent (and, therefore, quite typical) regional weaknesses, there are those related to human resources, the innovativeness of small- and medium-sized enterprises, and financial outlays for research, development, and implementation of innovations. The above-mentioned areas are directly related to potential innovation (Nawrocki and Jonek-Kowalska, 2022; Nawrocki and Jonek-Kowalska, 2023), i.e., the resource equipment of the economy enabling the initiation of innovation. This means a weakening of the initial situation for the development of innovation and the lack or low level of key determinants of innovation indicated in the literature on the subject (Hall *et al.*, 2022; Knudsen and Schleimer's, 2022; Tortorella *et al.*, 2022; Herstad and Sandven, 2020).

The long-term analysis of innovation in the countries of Central and Eastern Europe presented in the article makes it possible to distinguish five groups of countries that differ in the level and pace of innovation and the distance to the average innovation in the European Union. These groups are as follows:

1. Bulgaria: very low average innovativeness, low rate of innovation change, very large gap to the EU average;
2. Romania: very low average innovativeness, regression of innovation change, very large gap to the EU average;
3. Poland, Croatia, Latvia, Hungary, Slovakia: average level of average innovation, low pace of innovation change, large gap to the EU average;
4. Czech Republic, Estonia, Lithuania: high average innovativeness, high pace of innovation changes, small distance to the EU average;
5. Slovenia: leader in average innovation, low rate of change in innovation, zero distance to the EU average.

Moreover, the weakest areas of innovation in the surveyed economies are linkages, digitalization, innovators, and information technologies. The strongest advantages of innovation include finance and support, as well as human resources.

In the context of the obtained results, the following recommendations can be formulated for the analyzed region:

- Taking advantage of the inter-state exchange of knowledge and experience in the region due to the diversity of the strengths and weaknesses of innovation;
- Increasing state involvement in monitoring and supporting innovation in the private and public sectors;
- Improving the attractiveness of research systems, including increasing the scale of science–business cooperation;
- Providing enterprises with a system of financial and organizational incentives as part of their innovative activity;
- Strengthening ecological awareness due to the low level of sustainable development.

The results obtained in the article provide diagnostic knowledge in the field of innovativeness of developing economies located in Central and Eastern Europe. They also allow to the study of innovation from a long-term perspective, taking into account its initial level, pace of change, and distance to the EU

average. These results also facilitate classifying the surveyed countries in terms of the chosen innovation development paths.

The main research limitation of the conducted considerations is the use of secondary data contained in the EIS in the course of the analysis. Nevertheless, focusing research on a selected and important region of Europe allows for a better understanding of the mechanisms, as well as strengths and weaknesses of innovation in Central and Eastern Europe, which is important from a cognitive and practical point of view.

The direction for further research may include the development of more detailed area or international analyses. There may also be a concern regarding methodological issues related to the assessment of innovation proposed by various economic and scientific institutions.

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