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Innovativeness of the Polish industry in the context of changes in the spatial differentiation of innovativeness in new EU member states

Abstract: The paper addresses the issue of spatial differentiation in the level of industrial innovativeness in new EU member states from 2008 to 2017, with a particular focus on Poland. The purpose of the study is to attempt to describe changes in the spatial patterns of innovativeness in new EU member states (so-called EU13) and to indicate the position of Poland against the EU13 by using simple vector calculus. The period of analysis resulted from the availability of data. The paper presents matters related to the innovative activities of industrial enterprises and research and development (R&D) in Poland and other new EU member states. Selected features of innovativeness are shown as a relationship between expenditure and effect. The research confirms that the spatial pattern of industrial innovativeness in the EU13 significantly varies spatially between states. It is noteworthy that in the analysed period, the level of innovativeness in the Polish economy was relatively low compared to all EU countries as well as among the EU13. Moreover, the high growth figures obtained by Poland in most of the analysed features related to industrial innovativeness deserve to be emphasised. In 2008–2017 spatial differences in expenditure on R&D in the sector of industrial enterprises as well as their effects were highly stable.

Keywords: change in spatial patterns; industry; innovativeness; new EU member states; Poland; spatial differentiation

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INTRODUCTION

The article presents issues of spatial differentiation in the level of industrial innovativeness in the new EU member states in 2008–2017, with particular emphasis on Poland.

The development of a modern economy depends on the level of innovativeness of enterprises in introducing new, significantly improved products, advanced technologies and better systems of work organisation. The high level of innovativeness of industrial entities also has a significant impact on increasing the competitive advantage of the entire economy, enabling it, above all, to use its resources more efficiently. From the point of view of the possibility of achieving long-term economic growth, they are endogenous sources of development based on the internal human and material capital of a given area. A growth in innovativeness, as well as in the efficiency of the economy at its various levels, depends on many conditions including the size and direction of expenditure on R&D, innovative activities in industrial enterprises and the degree of automation of their production processes.

A structural system should be understood as a set of elements arranged according to specific principles of delimitation and grouping, and a set of relations between these elements. Structural changes bring about an increase in labour productivity and have a positive impact on the economic growth of countries and their regions. The contemporary development of the knowledge-based economy makes an analysis and evaluation of the economy's structures in terms of the degree of its modernity and innovativeness, extremely important.

The aim of the research is an attempt to measure changes in the spatial pattern of industrial innovativeness, in comparison to analytical approaches, in new EU member states and to indicate the position of Poland against the EU13 countries in 2008–2017. The analysis used a simple vector calculus. Research on structural changes in industrial innovativeness was based on the input-output relationship which made it possible to classify the EU13 countries, regarding the innovativeness of their industries, in terms of expenditure and effects, enabling an assessment of the scale of changes in the spatial patterns of industrial activity throughout the entire region.

The article presents selected issues concerning the innovativeness of industrial enterprises and R&D, in Poland and the new EU member states. The time frame resulted from the availability and comparability of data, hence the frequently different periods appearing in the study concerning individual issues of industrial innovativeness. The analyses concerned the scale and changes of the indicator of innovativeness in EU countries, i.e. the Summary Innovation Index (SII) which is part of an EU survey on the level of innovativeness in the economies of member states under the name of the European Innovation Scoreboard (EIS). Other categories of features analysed were those creating a favourable environment for the emergence of innovations, such as expenditure on R&D in the percentage of GDP, gross (GERD) and business expenditure on R&D (BERD) by state, employment in high-tech production or those that reflect the effects of the inputs, such as the value of high-tech products in total exports of individual EU member states.

METHODS AND DATA SOURCES

The applied method of examining structural change is a type of single-feature or quasi-feature test (taking into account a synthetic feature – composed of several, the so-called 'meta trait'). This study used single-feature studies.

In order to determine the change in the spatial pattern of industrial innovativeness, a vector calculus was used under the procedure proposed by Parysek (1976).

“A synthetic measure, and at the same time an image of the spatial structure of industry innovativeness in individual years, is the column vector K'_j (K'_1, K'_2, \dots, K'_n) as a vector drawn in m -dimensional Euclidean geometric space. The measure of changes in the spatial pattern is the angle between two vectors drawn in m -dimensional space for two different time sections. For practical reasons, the sizes of the angles between the two vectors are replaced with the value of the cosines of these angles. This function takes values in the range -1.0 to $+1.0$. Thus, the cosine of the angle between two vectors drawn in m -dimensional space is the quotient of the product of the values of these vectors by their dot product”, which is expressed by the formula (Parysek, 1976):

$$\cos K'_j K'_k = \frac{K'_j K'_k}{|K'_j| \cdot |K'_k|}$$

where:

$$K'_j K'_k = \sum_{i=1}^m c'_{ij} c'_{ik}$$

$$K_j^i = \sqrt{\sum_{i=1}^m c'^2_{ij}} \quad K_k^i = \sqrt{\sum_{i=1}^m c'^2_{ik}}$$

The arccosine calculated allows the size of the angle between the vectors to be determined, followed by the size of the change in the pattern under study. In the interpretation of the method used, a value of 1.0 for the function $\cos K'_j K'_k$ shows the stability of the pattern, $\cos K'_j K'_k = -1,0$ a complete inversion, $\cos K'_j K'_k = 0,0$ is a transformation of 50%, while $\cos K'_j K'_k = 0,7071$ is one of 25%.

The features adopted for the analysis, for comparability, were normalised using the following formula:

$$c'_{ij} = \frac{c_{ij}}{\sum_{ij} c_{ij}}$$

where c'_{ij} stands for the standardised element of the matrix P' , i.e. the matrix resulting from the transformation of the output data matrix. The vectors created in this way illustrate the share of the spatial unit in the examined phenomenon in particular years. A complement to the synthetic characterisation of changes in the spatial system of industrial innovativeness in the new EU member states was the classification of countries from the point of view of their position in the regional pattern of the studied phenomena. As a criterion for the division, rates concerning the average and the standard deviation were adopted (Parysek, 1976).

The source of data for the analysed features was the information available on the Eurostat database.

SELECTED R&D AND INNOVATIVE ACTIVITY ISSUES IN POLAND RELATIVE TO THE EU AND OTHER NEW MEMBER STATES IN ANALYTICAL TERMS

A characteristic feature of economic patterns is their variability over time, and this usually determines the relations between the elements and the whole set. In this way, employment and production structures are usually described, but also the region is treated as an element of a more extensive system (country) or as a whole in itself (Klamut, 1996). A broader approach, apart from the quantitative relation, includes qualitative relations, and from this perspective, studying the structure may include its effectiveness.

Structural changes in the economies of developed countries and international economic groups are manifested primarily in the reduction of production and employment in industries with obsolete technology and decreasing demand for their products, and at the same time accelerating the growth rate in industries using modern technologies for products for which there is a growing demand. This tendency occurs in all developed industrial countries; however, the pace and scale of change vary considerably (Winiarski, 2002).

The main factors include the development of science and technology. For this reason, it is essential to characterise the economy in terms of the degree of modernity of manufactured products and applied technologies. An increase in innovativeness and the introduction of new or significantly improved products or advanced technological processes contribute to fuller use of the resources available, as well as to an increase in the efficiency of the economy.

Innovativeness, according to the Oslo methodology, is the implementation of a new or significantly improved product, service or process, a new marketing method or a new organisational method in economic practice, workplace organisation or relations with the environment (*Podręcznik Oslo...*, 2008: 48). As a rule, it is distinguished by product, process, marketing and organisational innovation. Researching the innovativeness of industrial enterprises at a regional level, due to the availability of statistical data, is possible only concerning product and process innovation. Therefore these categories were included in the analysis. The set of entities based on which the innovativeness of the economy was assessed were enterprises that introduced at least one product or process innovation to the market (a new or significantly improved product or a new or significantly improved process) in the analysed period.

Innovative activity means all scientific, technical, organisational, financial and commercial activities that lead or are intended to lead to the implementation of innovation. Thus, innovative activities also include R&D that is not directly related to the creation of a specific innovation but develop a favourable environment for their creation (*Podręcznik Oslo...*, 2008: 49). R&D is one of the most critical factors and determinants of the innovative activity of enterprises. Its goal is to strive for continuous improvement, as well as to identify the primary opportunities and threats to the company.

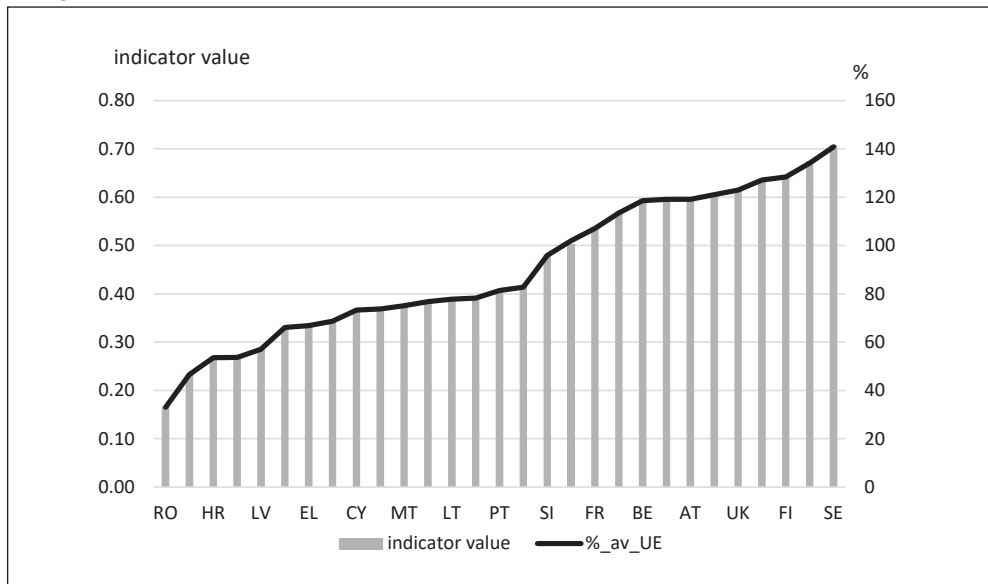
Innovative activity is one of the most critical areas of interest on the part of the European Commission. Its effect is cyclical and annual research on innovativeness in the form of the construction of an overall indicator based on 25 partial indicators. Innovativeness results are assessed at the national level for individual EU countries, i.e. the European Innovation Scoreboard (EIS) and the regional Regional Innovation Scoreboard (RIS).

All areas, both countries and regions, are aggregated into four main groups: innovation leaders, strong innovators, moderate innovators and the group of the weakest known as 'modest' innovators (*European Innovation...*, 2017).

The analysis of the research results contained in subsequent reports of the European Commission on innovativeness shows that its level in individual countries and within the four distinguished groups has changed over time. In the Innovation Union Scoreboard in 2016, taking into account, the average innovation index for the EU of 0.503, Sweden, Denmark, Finland, the Netherlands, the United Kingdom and Germany were included as innovation leaders with innovativeness results significantly above the average (Figure 1). The SII index for this group ranged from 0,609 to 0,708. Countries with SII values oscillating around the EU average (0,482–0,599) were in the strong innovators' group and included Austria, Luxembourg, Belgium, Ireland, France and Slovenia. The third most numerous were moderate innovators including Czechia, Portugal, Estonia, Lithuania, Spain, Malta, Italy, Cyprus, Slovakia, Greece, Hungary, Latvia, Poland and Croatia with indicator values ranging from 0,270 to 0,416. The results achieved by Bulgaria and Romania placed them significantly below the EU average and were thus classified as modest innovators.

Poland was a moderate innovator with a value of 0,270 in the survey for 2016. However, the values of the innovation index were in its lower level, and the position of Poland had changed little, as evidenced by the value of the index in 2010 and 2015 (*European Innovation...*, 2017). Despite the gradual increase in the value of this indicator in recent years, its change is highly unsatisfactory. In 2016, its value had increased by only 2,0% compared to the EU average in 2010, reaching 55%, while for the leader of the ranking, Sweden, it was almost twice as high – almost 141% of the EU average (Figure 1). The relative advantages of innovativeness in the Polish economy relate in particular to employment and investments in institutions conducive to innovation. Weaknesses, on the other hand, are related to the low activity of innovators and poorly developed research links and systems.

Figure 1. The value of the European Innovation Scoreboard in EU countries and its percentage to the EU average in 2016

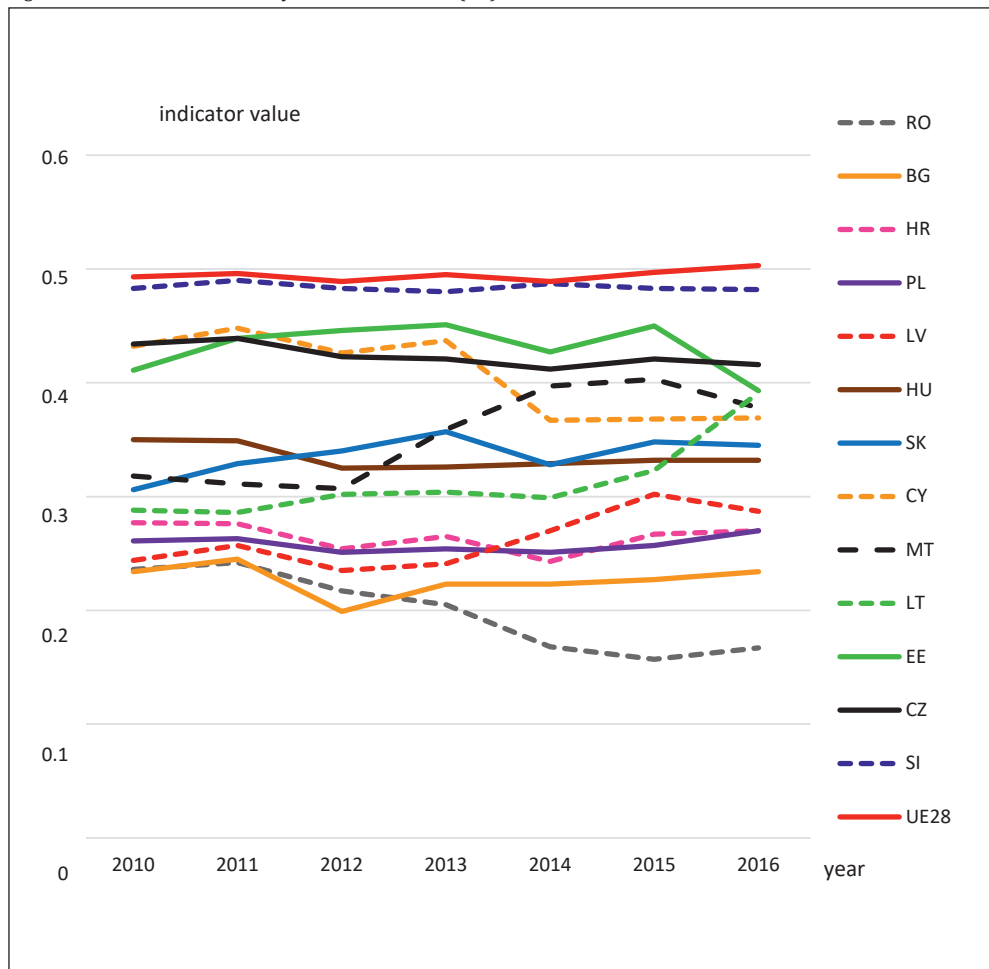


Source: author based on (*European Innovation...*, 2017)

The low position of Poland in terms of the level of innovativeness compared to other new EU member states should also be emphasised (Figure 2). The figure for the Summary Innovation Index (SII) was lower only in Romania and Bulgaria and was at a similar level to Croatia and Latvia. The value of the index in 2016 accounted for about 53% of the EU28 average and about 50% of its value in Slovenia, the country which showed the highest value of the total index among the new EU member states.

Changes in the value of the SII index for individual new EU member states showed a significant variation to the value of the index in the base year of 2010. Generally, the value of the index for the EU28 in the analysed period showed high stability as found in Slovenia, the country achieving the highest value among the new EU member states (*European Innovation...*, 2017). More significant fluctuations in the region took place in countries with both relatively high and low values of the total index. In the case of the former, a slight decrease in the value of the indicator for Czechia was noticeable, and after a period of growth, decreases occurred, especially in 2016 in Estonia and Malta.

Figure 2. Value of the Summary Innovation Index (SII) in new EU member states: 2010–2016



Source: author based on Eurostat data

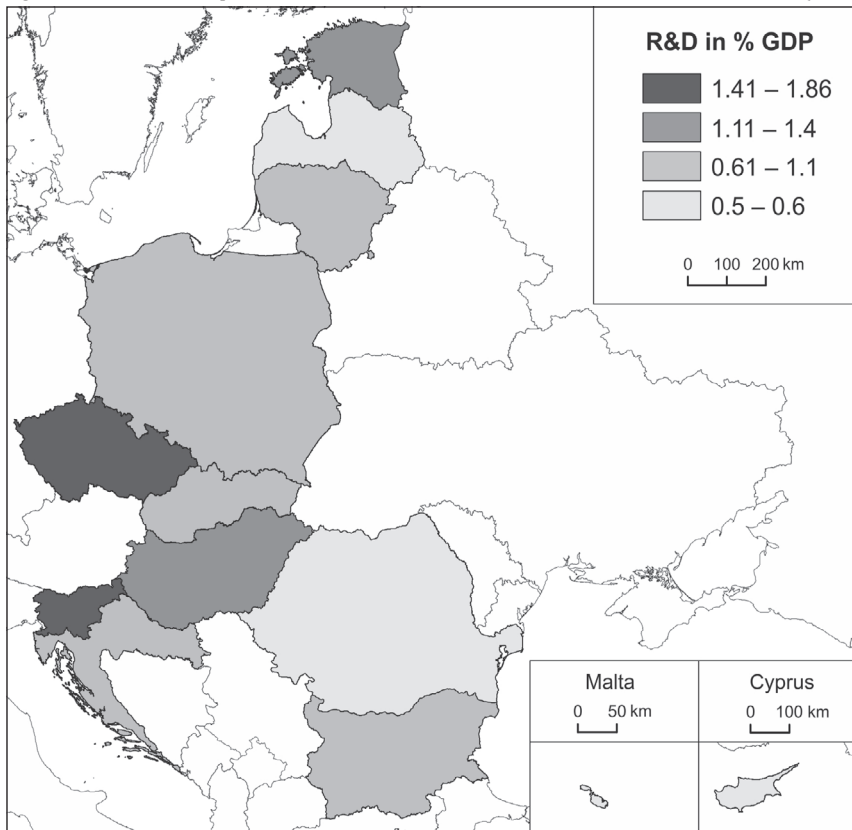
After a period of decline (2010–2011), Hungary recorded an increase while in Lithuania, an apparent increase appeared.

In the discussed period, Poland recorded relative stability, unfortunately at a low level with a slight increase in 2015–2016. A similar upward trend also appeared in Bulgaria. On the other hand, a significant decrease was recorded in Romania, which at the same time achieved the lowest value for the SII index among all new EU member states (*European Innovation...*, 2017).

Innovative activities include R&D activities that are not directly related to the creation of a specific innovation, and its expenditure is one of the factors determining the ability of countries to create innovation (Furman, Porter, Stern, 2002; Ulku, 2007) and provide an appropriate, beneficial and stimulating environment for the creation of innovative solutions in industry.

The level of expenditure on R&D in Poland has been highly unsatisfactory for many years. In 2017, the value of expenditure on R&D was 1,03% of GDP, with the EU average of 2,06% of GDP, i.e. twice as high. Much higher values in the region were characteristic of Hungary (1,35%), Czechia (1,73%) and especially Slovenia (1,86%) (Figure 3). The values of expenditure on R&D to GDP by half lower than those for Poland were recorded for Bulgaria, Latvia, Malta and Cyprus.

Figure 3. The level of expenditure on R&D to GDP in 2017 in the new EU member states (in %)



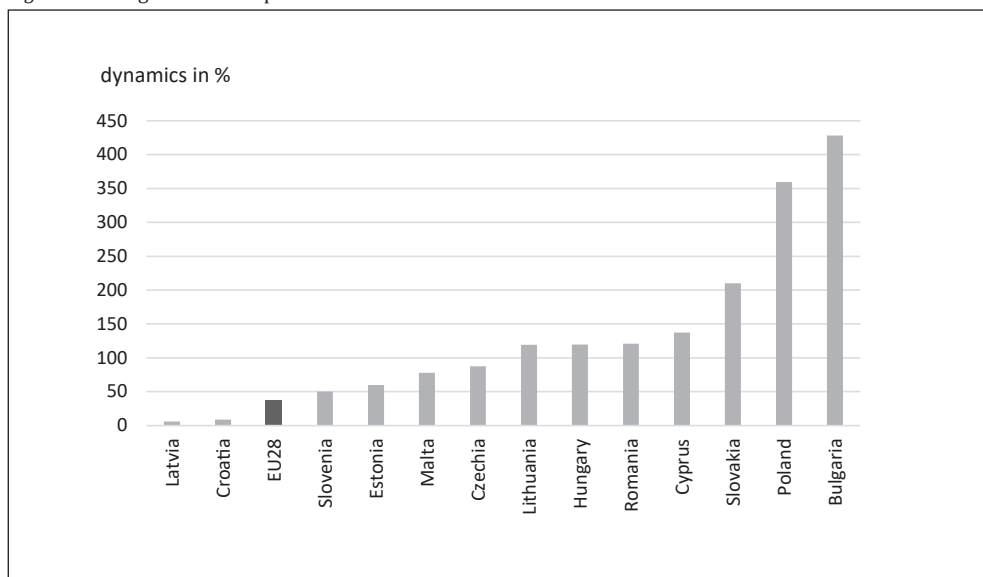
Source: author based on Eurostat data

On the other hand, a very positive phenomenon for Poland was the increase in expenditure on R&D. It should be noted that in 2008–2017 the average increase in R&D expenditure in the new EU member states was almost twice as high as the average growth for the entire EU, and amounted to 32% compared to 17% for the EU28. In this respect, growth in Poland was highly favourable. In the discussed period, Poland, with a growth of nearly 88% in 2017, was ranked first among the new EU member states, ahead of Slovakia (83%) and Bulgaria (67%) (Figure 4). Latvia and Malta were the only countries in this part of Europe that recorded a decline in expenditure on R&D. At the same time, it should be emphasised that the very high growth of expenditure in Poland also resulted from the low value for R&D in the starting year: in 2008 it was 0,6% of GDP.

In the analyses determining the innovativeness of industrial activity, expenditure on R&D in the GERD/BERD system plays a unique role. In the case of industry, the most important one is the scale of expenditure made by the industrial sector of BERD. The low value of the BERD index is typical for less developed countries where entrepreneurs find it more beneficial to acquire a foreign technology than to develop their own, which would require the mobilisation of substantial resources. In such economies, the research potential is usually maintained by the public sector, hence the expenditure of enterprises usually constitutes a much smaller part of the national GERD expenditure.

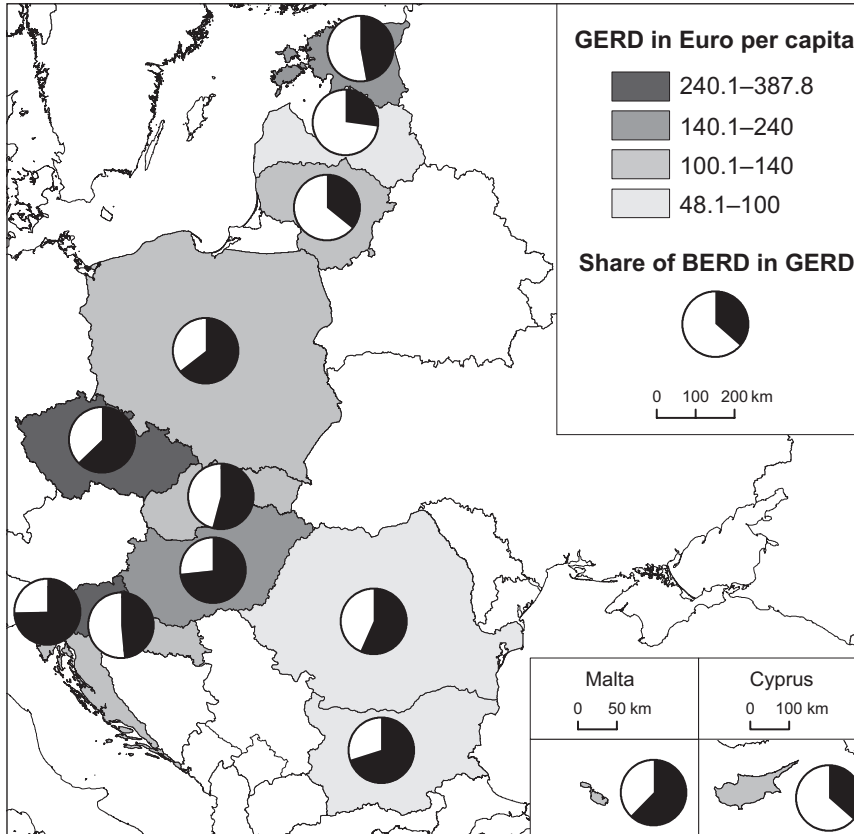
Poland, with over EUR 127 per capita in 2017, was one of those countries with low expenditure on R&D among the new member states (Figure 5). This value was indeed nearly 2.5 times higher than the lowest value achieved by Romania, but it was three times lower than the value for Slovenia and 2.5 times lower than that of Czechia. In the analysed year, the EU average was even higher at EUR 620 per capita, which was nearly five times higher than that in Poland.

Figure 4. Changes to R&D expenditure in the new EU member states: 2008–2017



Source: author based on Eurostat data

Figure 5. Patterns of domestic expenditure (GERD) and expenditure in the industrial enterprise sector (BERD) on R&D in 2017 in the new EU member states

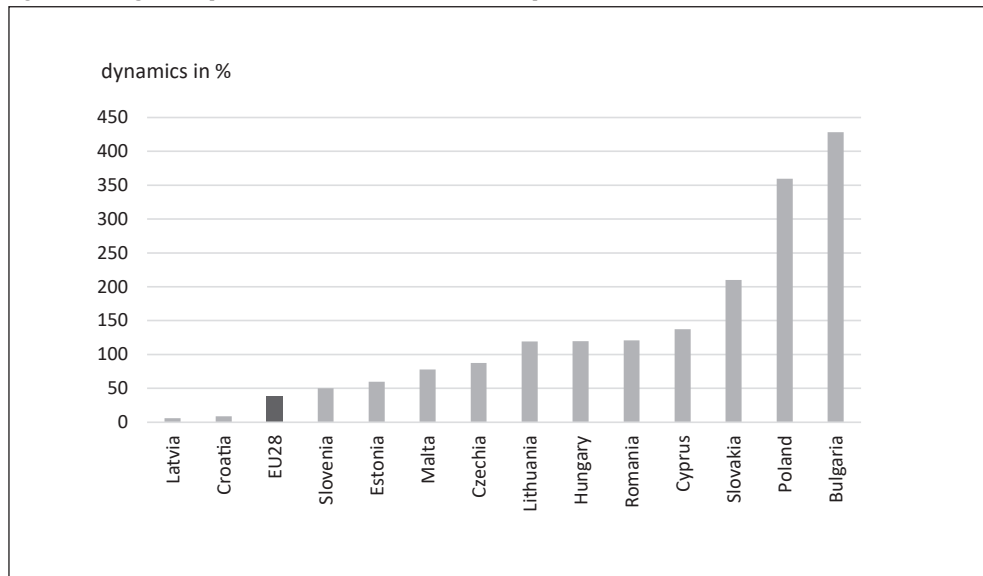


Source: author based on Eurostat data

The share of expenditure on R&D in the industrial enterprise sector in Poland out of the total national expenditure was at a medium level of 64%. However, it was lower than in Slovenia (75%), Hungary (73%) or even Bulgaria (70%). The structure of expenditure in Poland, however, was more favourable than in Latvia, Lithuania, Cyprus or Croatia (Figure 6). As in the case of the increase in R&D expenditure to GDP, change in the industrial enterprise sector was very favourable. The average increase in 2008–2017 was 140%, while the average for the EU28 was only 38%. Poland, with nearly 360%, was second among the EU13, only lower than Bulgaria (428%) and significantly ahead of Slovakia (210%) (Figure 6).

An essential measure in the analysis of industrial innovativeness is the scale of employment in high and medium-high technologies. Poland, with a share of 5,9% employed in 2018 in these categories out of total industrial employment, exceeded the EU average of 5,8%. Much higher values, oscillating around 10% of those employed in high and medium-high technologies were recorded in Slovakia, Czechia, Slovenia and Hungary. The lowest shares of less than 2% of total employment in industry were recorded in Cyprus and Latvia (Figure 7). Also in terms of employment growth in high and medium-high technologies, in 2009–2018 the new member states achieved a higher

Figure 6. Changes in expenditure on R&D in industrial enterprises in the new member states in 2008–2017 in %



Source: author based on Eurostat data

growth rate than the EU28 average reaching almost 18%, while the EU average was less than 4%. However, in terms of employment growth in high and medium-high technologies, the new member states were quite diversified. Romania, with a relatively high share (6,4%), achieved the highest growth reaching almost 40% (Figure 8) with Slovakia (over 31%) and Cyprus (nearly 29%) achieving high increases as well. The latter, however, had the lowest share value (less than 1% in 2009) of employment in high and medium-high technologies among all new member states. Malta was the only country that recorded a decline in employment, and Estonia did not see any change. Poland’s position in this respect, with a result of less than 23%, was one of those new member states with an average scale of employment growth.

The presented elements of the analysis of industrial innovativeness can be included in the category of expenditure on this activity. Hence, it is possible to apply the approach involving a relation of inputs to the figures, which are the result of these relationships. It allows the use of a simple input-output method in research on the innovativeness of economies. The ability of an economy to create, implement and apply innovations and new technological solutions, with appropriate human capital resources, is now recognised as the underlying factor of this growth and development. Often, input-output methods are used in research on the diffusion of innovation embodied in various types of products. This type of diffusion, analysed at the sectoral level, is most often described based on information on the innovativeness potential of individual sectors and the strength of inter-sectoral connections expressed through appropriate input-output factors. The innovativeness potential of individual sectors of the economy is most often identified with the amount of expenditure (current and/or cumulative) incurred on R&D, which are then compared with a specific category of effects. There is also a certain duality of R&D expenditure: on the one hand, it is the main factor necessary to create and implement innovations, and on the other, it makes it easier for companies to obtain

Figure 7. Employment in high and medium-high technologies in 2018 in the new EU member states

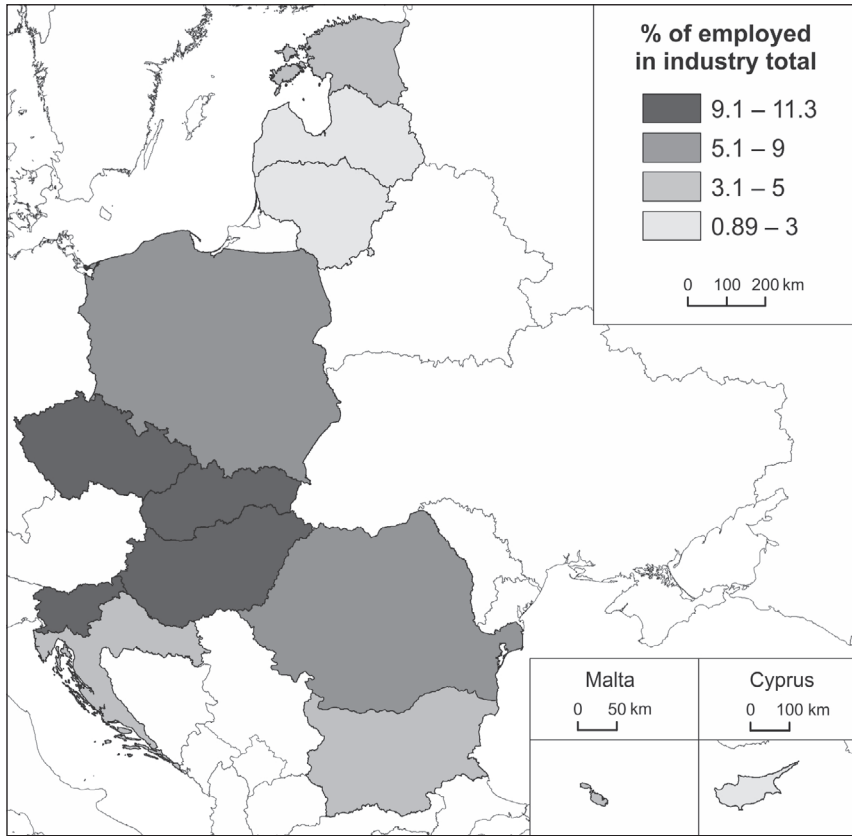
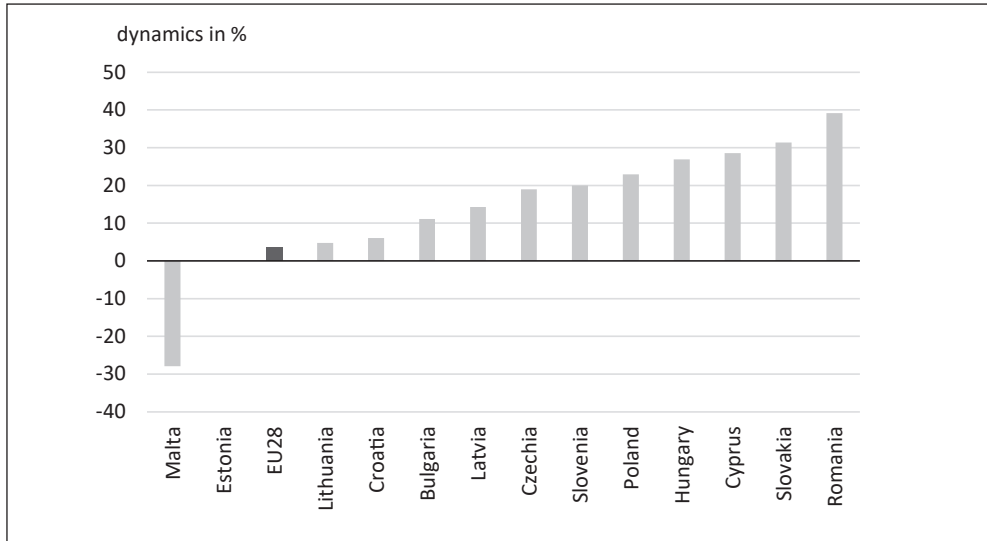


Figure 8. Employment changes in high and medium-high technologies in the new EU member states: 2009–2018



Source: author based on Eurostat data

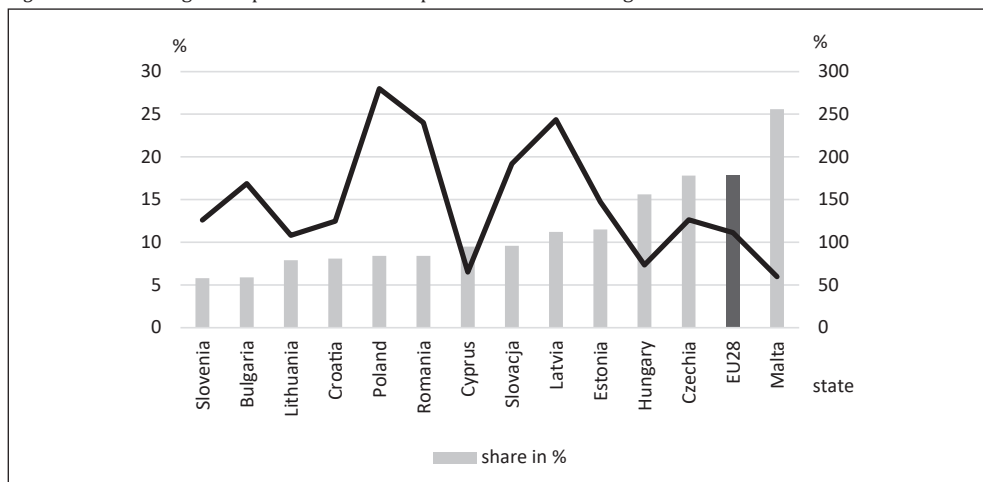
knowledge and innovation from external sources (Guan, Chen, 2009). The quantitative assessment of the effects of inter-sectoral diffusion of innovation within a given economy is based on the assumption that the size of the benefits in a given sector depends on the strength of its links with sectors with high innovative potential.

An important parameter, used primarily to assess the effects of innovative activity in industrial enterprises, is the share of production of new and significantly improved products in the value of total production sold. Thus, the result of expenditure expressed in the form of BERD or the scale of employment in high and medium-high technology industries may be the scale of manufactured high-technology products in total exports. Taking into account the above parameter for Poland, its level is highly unsatisfactory, especially concerning the expenditure defined above (Nowak, 2012). The reasons for this are complex, ranging from the financial crisis that began in the world economy in 2008 and affected the investment and export sphere of companies with foreign capital operating in Poland, to the consolidation of the position of the Polish economy as a “supplier” country for many companies with German capital that carry out production in Poland, which is in the phase of maturity and standardisation of the product life cycle (Brezdeń, 2016, 2018)

The share of high-tech products in the value of Polish exports in total was only 8,4% in 2018, with the EU28 average being close to 18% (Figure 9). It should be emphasised that this was also much lower than the average for the new member states, which was at a level of over 11%. Positive expression of the share of high-tech products in Polish exports in total was its highest growth among all new EU member states in 2007–2018. For Poland, this value in 2018 was 280% compared to the base year of 2007. Slightly lower results were achieved by Latvia (243%) and Romania (240%) with the average for the entire region at 150%. However, the highly unsatisfactory relatively low level of the share of high-tech products in Polish exports achieved in 2018 should be remembered.

A comparison of the competitiveness of Polish industrial enterprises with different levels of technological advancement shows that companies from low technology

Figure 9. Share of high-tech products in total exports in 2018 and changes in new EU member states: 2007–2018



Source: author based on Eurostat data

industries are relatively more competitive than industrial enterprises in general, as they achieve relatively higher revenues from the sale of new-to-the-market goods than the industrial sector taken as a whole (Weresa, 2018). These trends regarding the sale of innovative products are one of the reasons for the relatively low share of high-tech goods and knowledge-intensive services in Polish exports. Countries with a similar level of development, such as Estonia, Czechia, Slovakia or Hungary, had much higher indicators (Figure 10). This comparison shows Poland's technological backwardness compared to the majority of moderately advanced innovators in the EU (Gajda, 2015; Rachwał, Wiedermann, Kilar, 2009; Weresa, 2018). On the other hand, the changes show a positive trend.

AN OVERALL APPROACH TO CHANGES IN THE SPATIAL DIFFERENTIATION OF INDUSTRIAL INNOVATIVENESS IN NEW EU MEMBER STATES

The analytical aspect of the issue dominates in economic and geographical studies of spatial systems, as evidenced in the first part of this article. It was devoted to selected issues of innovativeness in the spatial structure of the Polish industry compared to other new EU member states. It focused on an analysis of the elements of industrial innovativeness and R&D, creating specific spatial patterns and the changes taking place in 2008–2017. However, they did not allow the determination of the overall change in a given time. Hence, in the following part, an attempt was made to synthetically characterise changes in the spatial system of industrial innovativeness, rarely undertaken in the literature. The reason for conducting synthetic research is based on the belief that different kinds of changes characterise the system as a whole rather than those that concern individual elements of the spatial system.

The research on structural changes in industrial innovativeness in the new EU member states represented single-feature research and was made for two features showing dependencies in the input-output relationship. They were (1) R&D expenditure in the industrial enterprise sector in millions of euros, and (2) export value of high-tech products in millions of euros.

In the years 2008–2017, the spatial structure of R&D expenditure in industrial enterprises in the new member states was relatively stable. The changes in the spatial structure were not significant as indicated by $\cos_{2008,2017}$ amounting to 0,912306. The calculated arccosine gives an angle of $24^{\circ}17'$. It means that the spatial structure of BERD expenditure in the EU13 changed by 13,5% in 2017 compared to 2008. An expression of the relative stability of the spatial structure of BERD expenditure in the new EU member states in the analysed period is the slight changes in the classification of countries in terms of their share in the regional system (the participation indicators to the average share and standard deviation were adopted as the criterion of division). In 2017, only Croatia moved from the medium class in 2008 to the low class and Bulgaria from the low class to the medium (Table 1). However, changes in the position of countries within individual classes, especially the largest, are noticeable. In 2008, Czechia was a country whose expenditure accounted for nearly 32% of the total BERD expenditure of industrial enterprises among new member states. Poland was second with a share of only 18,7%, and third was Hungary with 15,4%. In 2017, Poland moved to the leading position with 35% of the total expenditure of industrial enterprises in the region, and the shares of Czechia decreased to 24,2%, and Hungary to 13,7%.

Table 1. Classification of new EU member states in terms of expenditure on R&D in industrial enterprises

Share	STATE 2008	STATE 2017
low	Cyprus	Cyprus
	Malta	Latvia
	Latvia	Malta
	Bulgaria	Lithuania
	Lithuania	Estonia
	Estonia	Croatia
medium	Slovakia	Bulgaria
	Croatia	Slovakia
	Romania	Romania
	Slovenia	Slovenia
high	Hungary	Hungary
	Poland	Czechia
	Czechia	Poland

Source: author based on Eurostat data

In the case of the export value of high-tech products, the spatial pattern of the new member states in 2009–2018 was even more stable with a $\cos 2009,2018$ value of 0,938401. The calculated arccosine gives an angle of $20^{\circ}22'$. It means that the spatial structure of exports of high-tech products in the new EU member states had changed in 2018 only by 11% compared to 2009.

This more significant stability in terms of the value of exports of high technology products was reflected in even smaller shifts in the classification of countries in terms of their position in the regional system. In this case, only Slovenia moved from the medium class to the low class (Table 2).

However, there are slightly different shifts among the countries with the highest share in the total value of exports of high-tech products. In this case, Hungary lost the leading position in 2009, and its share in the total exports of the region decreased from 32,8% in 2009 to 18,4% in 2018. Unfortunately, Poland did not regain the leading position, unlike expenditure by industrial enterprises, and its share increased from 13,8% in 2009 to only 20,5% in 2018. The leading position was taken by Czechia whose share in 2018 had increased from 30,5% to 33,8%.

Table 2. Classification of new EU member states in terms of export value of high-tech products

Share	STATE 2009	STATE 2018
low	Cyprus	Cyprus
	Latvia	Malta
	Estonia	Croatia
	Bulgaria	Latvia
	Croatia	Bulgaria
	Lithuania	Estonia
	Malta	Slovenia
		Lituania

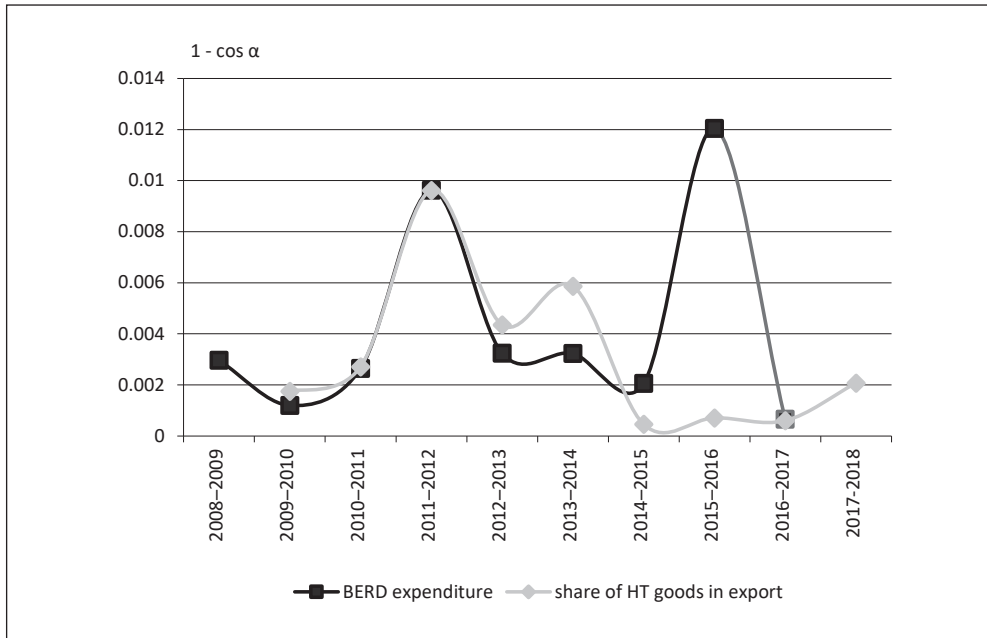
medium	Slovenia	Romania
	Slovakia	Slovakia
	Romania	
high	Poland	Hungary
	Czechia	Poland
	Hungary	Czechia

Source: author based on Eurostat data

The research indicates that individual new EU member states often create a diverse environment conducive to innovative activity in industry both in terms of the scale of expenditure on R&D and the effects achieved. A good example is Poland, which in recent years, despite a significant increase in R&D expenditure among industrial enterprises, has not achieved sufficient increases in effects; it recorded a lower export value of high-tech products in relation to much smaller countries such as Czechia or even Hungary.

It should be emphasised that in the analysed period there was a significant increase in the disproportion in expenditure on R&D in industrial enterprises among individual countries of the region. It is evidenced by the calculated coefficients of variation, amounting to 117% in 2008, and 133% in 2017. In the case of the effects of expenditure in the form of the export value of high-tech products, the disproportions, although slightly more substantial, are gradually decreasing, as evidenced by the values of the coefficients of variation in the analysed period decreasing from 140% in 2008 to 128% in 2017. Therefore, it can be concluded that the efficiency of using expenditure in

Figure 10. Changes in the patterns of expenditure on R&D in industrial enterprises and the value of high technology product exports in individual years (2008–2018) in new EU member states



Source: author based on Eurostat data

R&D, resulting in the scale of the value of manufactured high-tech products in individual new member states, varies significantly.

In order to determine only the size of the changes in the spatial pattern of both inputs and results in the form of the value of exports of high-tech industrial products, in individual years of the period 2008–2017, it was necessary to give a slightly different interpretation of the calculated $\cos K^j K^k$ function. The expression $(1 - \cos K^j K^k)$ will be a measure of changes in the structure. The analysis of the results shows that slightly more significant fluctuations in the structure (while generally insignificant throughout the period) took place in 2011–2012 and 2015–2016 in the case of expenditure by industrial enterprises in R&D, and in 2011–2012 and 2013–2014 in the case of export value of high-tech products (Figure 10). Such an abrupt distribution of changes in R&D expenditure in enterprises to the production value of high-tech products may prove that the effects of expenditure on R&D in the form of specific high-tech products appear with an inevitable delay. This regularity may be confirmed by the standard deviation in exports of high-tech products in 2017–2018.

SUMMARY AND CONCLUSIONS

The conducted analyses show a relatively low level of innovativeness in the Polish economy in the analysed period, not only compared to the EU28 but also among the new EU member states. This situation has been influenced by the underfunding of R&D and innovativeness, which makes it difficult to conduct more technologically advanced research. Many years of neglect in financing R&D hinder the expansion of Polish companies into the markets of technologically advanced goods and services (Weresa, 2018).

It should be emphasised that the growth dynamics of R&D expenditure in Poland in 2008–2017 was high compared to the new EU13 countries, and this also translated into an increase in R&D expenditure per capita.

The share of expenditure on R&D in Poland in the sector of industrial enterprises is average compared to the new EU countries, while the dynamics of this expenditure in industrial entrepreneurs (BERD) is favourable. After many years of domination of the public sector in the structure of R&D financing and a relatively small share of the private sector, these proportions have changed. The share of enterprises in R&D financing has significantly increased, which is a very positive phenomenon. Unfortunately, the share of those employed in the production of high-tech products is still average, while the share of high-tech products in the total export of goods is unsatisfactory in Poland. Particularly high values obtained by Poland in these features, however, deserves emphasis.

In 2008–2017, the spatial pattern of expenditure on R&D in the industrial enterprise sector in the new EU member states, despite significant growth in many areas, did not change radically and reached over 13%. The change in the spatial structure of the export value of high-tech products was transformed to a lesser extent – over 11% which demonstrates the still low effectiveness of R&D in creating innovation in industry in the region. The structure of industrial innovativeness in the new EU member states is spatially diversified. Changes in the spatial structures of R&D expenditure in enterprises and the production value of high-tech products are sharp; in the case of the latter, changes appear with a delay in relation to expenditure. Noteworthy are the

increasing disparities between countries in terms of expenditure on R&D, which are accompanied by decreasing disparities in the spatial distribution of the value of high-tech products. It also confirms the diversified effectiveness of expenditure on R&D in the form of high-tech products in individual new EU member states, which in the case of Poland is unsatisfactory.

References

- Brezdeń, P. (2016). Wybrane aspekty wpływu kapitału zagranicznego na gospodarkę Dolnego Śląska – ujęcie przestrzenne [Selected Aspects of the Influence of Foreign Capital on the Lower Silesia Economy – a Spatial Perspective]. *Prace Komisji Geografii Przemysłu Polskiego Towarzystwa Geograficznego* [Studies of the Industrial Geography Commission of the Polish Geographical Society], 30(2), 72–94.
- Brezdeń, P. (2018). Research Topics and Changes in the Spatial Structure of Innovativeness of Polish Industry in 2005–2015. *Prace Komisji Geografii Przemysłu Polskiego Towarzystwa Geograficznego* [Studies of the Industrial Geography Commission of the Polish Geographical Society], 32(4), 205–226.
- Eurostat. (2019, October 14) Retrieved from: <https://ec.europa.eu/eurostat/data/database>.
- European Innovation Scoreboard 2017. (2017). Retrieved from: https://www.rvo.nl/sites/default/files/2017/06/European_Innovation_Scoreboard_2017.pdf (Accessed on: 2019, November 12)
- Furman, J. L., Porter, M. E., Stern, S. (2002). The determinants of national capacity. *Research Policy*, 31(6), 899–933.
- Gajda, W. (2015). Innowacyjność polskiego przemysłu na tle przemysłu światowego. *Prace Komisji Geografii Przemysłu Polskiego Towarzystwa Geograficznego* [Studies of the Industrial Geography Commission of the Polish Geographical Society], 29(1), 42–55.
- Guan, J., Chen, Z. (2009). The technological system of Chinese manufacturing industry. A sectorial approach. *China Economic Review*, 20(4), 767–776.
- Klamut, M. (1996). *Ewolucja struktury gospodarczej w krajach wysoko rozwiniętych*. Wrocław: Wydawnictwo Akademii Ekonomicznej im. Oskara Langego.
- Nauka i technika w 2015 r. Science and technology in Poland in 2015*. (2016). Informacje i Opracowania Statystyczne. Warszawa: GUS; Urząd Statystyczny w Szczecinie.
- Nowak, P. (2012). Poziom innowacyjności polskiej gospodarki na tle krajów UE. *Prace Komisji Geografii Przemysłu Polskiego Towarzystwa Geograficznego* [Studies of the Industrial Geography Commission of the Polish Geographical Society], 19, 153–168.
- Parysek, J. (1976). Zmiany struktury przestrzennej przemysłu Polski w latach 1960–1973. Próba miernika syntetycznego. *Przegląd Geograficzny*, 48(2), 253–268.
- Podręcznik Oslo. Pomiar działalności naukowej i technicznej. Zasady gromadzenia i interpretacji danych dotyczących innowacji*. (2008). Warszawa: Ministerstwo Nauki i Szkolnictwa Wyższego, Departament Strategii i Rozwoju Nauki.
- Rachwał, T., Wiedermann, K., Kilar, W. (2009). Rola przemysłu w gospodarce układów regionalnych Unii Europejskiej. *Prace Komisji Geografii Przemysłu Polskiego Towarzystwa Geograficznego* [Studies of the Industrial Geography Commission of the Polish Geographical Society], 14, 31–42.
- Ulku, H. (2007). R&D, innovation, and growth. Evidence from four manufacturing sectors in OECD countries. *Oxford Economic Papers* 59(3), 513–535.
- Weresa, M. (2018). Działalność badawczo-rozwojowa i innowacyjna a konkurencyjność polskiej gospodarki. In: *Rola miast w kształtowaniu przewag konkurencyjnych Polski*. Warszawa: Oficyna Wydawnicza SGH – Szkoła Główna Handlowa, 149–170 (Polska. Raport o konkurencyjności, 2018). Retrieved from: https://www.researchgate.net/publication/326370024_Dzialalnosc_BR_i_innowacyjna_a_konkurencyjnosc_polskiej_gospodarki (Accessed on: 2019, October 13)
- Winiarski, B. (2002). *Polityka gospodarcza* (2nd ed.). Warszawa: Wydawnictwo Naukowe PWN.

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