Creativity and Innovation in Polish Universities: The Knowledge Triangle Approach

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Abstract. Recently, the role of universities is gradually shifting from academic focus towards more entrepreneurial and innovation-oriented. This requires creativity and interaction, in terms of innovation, research and educational activities of universities. The challenge of developing creativity is crucial particularly for countries like Poland, which still do not belong to the leaders in innovation. The aim of this paper is to identify the position of Polish universities in terms of creativity in comparison to other EU countries from Central and Eastern Europe (CEE). The analysis is carried out using the "knowledge triangle" concept, encompassing involvement of universities in education, research, innovation and entrepreneurship. The analysis covers selected indicators characterizing each of the vertices of the knowledge triangle considered in the context of activities undertaken by universities. It is based on data obtained from Eurostat and OECD databases for the period of 2010–2016.

A comparative analysis of these indicators showed that Poland stands out in the CEE region in terms of the relatively high share of the higher education sector in conducting scientific research and the availability of scientific staff resources. However, this does not translate into the leading position of Polish universities when it comes to creativity measured by citations or the number of patents. Poland's advantages in terms of creativity are only visible in industrial design. Therefore, the effects of the interactions within the "knowledge triangle" in Poland are insufficient to stimulate creativity and broaden the involvement of national actors in global research and innovation networks.

Keywords: Creativity · Knowledge triangle · Innovation · Poland · CEE

1 Introduction

The creation and use of knowledge have become one of the key focuses of entrepreneurs and scientists. The value and importance of knowledge is also highly appreciated by policymakers and the entire society. Dynamic development of information and communication technologies (ICT) reinforced the importance of knowledge-based economy, which is accompanied by the growing internationalization of businesses, research and development and innovation. Such change is also visible in the higher education sector

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and its key players – universities. Recently, the role of universities is gradually shifting from academic focus towards more entrepreneurial. Currently, the broader dimension of innovation is gaining importance, such as innovations in the public sector focused on new quality of services provided to society [1], as well as social innovations - new products, models, institutional solutions, etc. bringing a change in social relations [2]. However, innovation relies, among others, on creativity and interaction, which is described by the concept of the "knowledge triangle" referring to innovation, research and educational activities of universities [3, 4]. Universities should focus not only on teaching and knowledge creation, but also on its commercialization [5]. This challenge is crucial particularly for countries such as Poland, which still do not belong to the leaders in innovation [6].

The aim of this article is to identify the position of Polish universities in terms of creativity in comparison to universities' performance of other countries from Central and Eastern Europe. The analysis is based on the data from the pre-pandemic period (2010–2016).

The article consists of five following sections: introduction, literature review, research methodology, research results and discussion with conclusions. The introductory remarks outlined above present the objectives and scope of this study. The following section, literature review, presents the theoretical framework that allows to link innovation with creativity. The next part of the paper aims at identifying the position of Polish universities among other EU Member States in terms of creating new knowledge, its dissemination and protection. The analysis is based on data obtained from Eurostat [7] and OECD [8] databases and covers the period of 2010–2016. The paper conclusions present a summary of research results and recommendations on the possible paths for developing creativity in Polish universities.

2 Theoretical Framework: Creativity and Innovation How They Are Connected?

Creativity is a multi-faceted notion that may be explained from various points of view, including psychological, sociological, philosophical, and economical. Considering the latter one, numerous research studies on creativity and its dimensions stress the relevance of creative thinking in the creation of innovation. In fact, Joseph Schumpeter used the term "creative destruction", which means destruction of existing structures and solutions and replacing them with new ones, which may result in a new product, discovery of new resources, emergence of new markets, changes in production methods or organization of production [9]. According to Schumpeter there is a distinction between invention (creativity) and innovation because the latter arises only when the novelty is brought to the market, followed by its distribution and imitation. Thus, entrepreneurship is also essential to develop something previously unknown (creative) and distinct from existing alternatives (innovation). Innovation is crucial because it allows for the development of individuals, organizations and societies [10–13].

Researchers examine the relationship between creativity and innovation from various perspectives, including organizations [14, 15], human talent development [16], education [17, 18] and science [19]. All of these analyses reach the same conclusion and emphasize the interdependence of creativity and innovation. Creativity refers to people's

ability to generate new ideas, whereas innovation refers to the transformation of these ideas into new economic solutions. For this reason, it is crucial to educate and encourage young entrepreneurs and scientists to develop creativity and skills to transform it into innovation [20]. The rapid development of new technologies and modernization of work professions, make innovativeness, entrepreneurship, and soft skills increasingly important for professional success [21]. These skills are often treated on a par with technical and scientific skills and determine employment opportunities along with corresponding wages [22, 23]. Many studies show that technological skills are important to start a business, but to succeed in business, they must be supplemented with flexibility, creativity, perseverance and social skills necessary to create teams, manage teamwork, and deal with clients and other stakeholders [24]. This allows to conclude that innovativeness and entrepreneurship require a combination of different types of creativity. This is also indicated by Richard Florida in the concept of the creative class emphasizing its internal diversity [25, 26]. Florida identifies two main groups of creative people: a super-creative core and creative professionals. The first group is made up of scientists, engineers, artists, designers and people shaping the views of society, whereas the second one consists of professionals seeking to solve the problems identified by the creative core. These include managers and employees employed in knowledge-intensive industries, such high-tech sectors, the legal and healthcare professions, financial services and business management [26]. Florida identifies three components that determine creativity: technology, talent and tolerance. They constitute, so called, "3T approach" showing that creativity is diverse geographically, which is reflected in the unequal innovativeness of economies [26]. The social and location dimension of creativity and innovation cause the need to compete for talents. That is why contemporary universities should not only teach and do research, but also focus on shaping talents [27].

The concept of the "knowledge triangle" describing the new role of universities focuses on stimulating creativity and innovation seems to be an extension of Florida's thesis. This "knowledge triangle" has three vertices that describe the activities of a contemporary university: education/learning, research/discovery, and innovation/engagement [28]. The linkages between these three aspects encourage multidirectional knowledge flows, which can boost economic growth dynamics [29].

Functional model of interactions between the three vertices of the "knowledge triangle" includes:

1) Interactions between scientific research and education, which take place, among others, through geographical and sectoral mobility of graduates, post-graduate studies, using the results of basic and applied research as the basis for teaching in order to improve the alignment of graduates' skills with the needs of enterprises.
2) Interactions between research and innovation, aimed at supporting and intensifying knowledge transfer by, e.g.:

   - public-private partnership (e.g. clusters, science parks),
   - commercialization of publicly funded research (intellectual property rights),
   - research and development services provided by universities for business,
   - spin-off companies and academic start-ups,
   - knowledge and technology transfer offices,

- business incubators,
- open science platforms.

3) Interactions between education and innovations implemented through: cooperation for the development of entrepreneurial culture (e.g. industry-oriented doctoral programs) and support for the development of business-related competences (trainings on business plan creation, management, etc.) [30].

According to empirical studies on universities' role in the knowledge triangle, there is no one widely cited model that describes the above-mentioned interactions. The reason for this is that education systems are usually country-specific, thus universities differ a lot looking at their characteristic, functions they perform and goals they serve in terms of education, knowledge creation and innovation development [31].

Summing up, the theories described above show that regional specificity should be considered while conducting research on creativity and innovation. Changes in country's position related to its innovativeness can be described using various indicators (e.g. expenditures on R&D, number of patents) and they are associated with other elements of the "knowledge triangle", such as level of education and scientific research potential. Human resources are particularly important because, as indicated above, creativity that determines innovation is an attribute of a human being.

3 Research Objective, Methodology and Data

The literature review presented above leads to the conclusion that innovation is associated with creativity, which is affected by, among others, quality of research and education, especially at the university level. Therefore, several questions arise about the role of Polish universities in creating new knowledge.

- How creative are universities in Poland compared to other EU countries, especially those from Central and Eastern Europe?
- What is the contribution of Polish universities to increasing knowledge resources and its dissemination in the form of scientific publications, or - if justified - its protection through patents?
- To what extent does the direction and pace of changes in the creativity of Polish universities give a chance to improve the innovativeness of the economy?

This article aims to present answers to the research questions listed above.

This study presents Poland with comparison to other Central and Eastern European countries that joined the European Union as a result of enlargements in 2004, 2007 and 2013. Thus, the EU countries to which Poland's position is compared are the Czech Republic, Hungary, Slovakia, Estonia, Latvia, Lithuania, Slovenia, Romania, Bulgaria and Croatia. The analysis is carried out using the framework the "knowledge triangle" concept discussed above, encompassing involvement of universities in education, research, innovation and entrepreneurship. The analysis will cover selected indicators characterizing each of the vertices of the "knowledge triangle" considered in the context of activities undertaken by universities. The indicators are synthetically presented

in Table 1. The data used in this study comes primarily from the Eurostat and OECD databases.

Table 1. Indicators of university innovativeness and creativity corresponding to the "knowledge triangle" concept. Source: own elaboration

Type of university activities according to the concept of the knowledge triangle	Indicators
Research	Expenditures on research and development (R&D) carried out by the higher education in relation to GDP
	Participation of scientists and engineers in the 25–64 age group as % of the working population
	Percentage of scientific publications among 10% of the most cited publications worldwide as a % of all scientific publications of the country
	Patents, trademarks, utility models in relation to GDP
	Patents filed at the same time for 5 key patent offices of the world (patent families) by universities and research institutions
Education	Public expenditures on higher education (% of GDP)
	The percentage of people aged 25–34 who have completed tertiary education (ISCED 5–8) (%)
	Foreign doctoral students (as a percentage of all doctoral students)
	Population aged 25–64 completing supplementary programs (lifelong learning) as % of the total population
Innovation (and entrepreneurship)	Research and development activities carried out by higher education and financed by private entities (enterprises and private non-profit organizations) (% of GDP)
	Share of employees aged 25–64 with higher education (%)
	Share of enterprises cooperating with universities or other higher education institutions (%)
	Synthetic indicator of the countries' potential to be part of global education, innovation and research networks

4 Research Results and Discussion

4.1 Creativity as the Result of Scientific Research

Knowledge creation requires the expenditure on research and development, which is also considered as one of the factors of determining innovativeness of economies (cf. e.g. [31, 32]). What is the level of the expenditures on R&D in the higher education sector? Is there a systematic increase of the expenditures on R&D in relation to GDP that would enable permanent support for creativity and innovation in universities? Table 2 presents Poland's position with comparison to other EU Member States from Central and Eastern Europe (CEE) in terms of expenditures on research and development (R&D) carried out by higher education sector in relation to GDP in 2010–2016.

Table 2. Expenditures on research and development (R&D) carried out by higher education (as a percentage of GDP) in 2010–2016. Source: own elaboration based on [7, 8]

	2010	2011	2012	2013	2014	2015	2016
EU28	0.47	0.46	0.47	0.47	0.47	0.46	0.47
Bulgaria	0.07	0.05	0.05	0.05	0.07	0.05	0.04
Croatia	0.21	0.21	0.20	0.20	0.20	0.20	0.28
Czech Republic	0.27	0.38	0.49	0.52	0.50	0.48	0.34
Estonia	0.60	0.64	0.68	0.73	0.64	0.62	0.46
Hungary	0.23	0.24	0.23	0.20	0.18	0.17	0.13
Latvia	0.24	0.34	0.33	0.26	0.28	0.31	0.19
Lithuania	0.42	0.49	0.48	0.52	0.54	0.58	0.33
Poland	**0.27**	**0.26**	**0.30**	**0.25**	**0.27**	**0.29**	**0.30**
Romania	0.11	0.11	0.10	0.08	0.06	0.09	0.05
Slovakia	0.17	0.23	0.27	0.27	0.30	0.51	0.22
Slovenia	0.29	0.29	0.29	0.27	0.25	0.22	0.22

Poland spends a relatively small percentage of GDP on R&D (0.97% in 2016), by half less than the EU average (2.03% in 2016). From the group of EU countries from Central and Eastern Europe, Poland is ahead of Slovenia, the Czech Republic, Estonia and Hungary (Eurostat, 2018). However, when it comes to expenditures on R&D activities conducted by universities, Poland's position in the CEE is slightly better. In 2016, Poland allocated 0.3% of GDP to R&D to research conducted by higher education. This is still below the EU28 average (0.47%), but only three countries from the analyzed group achieved better results in this respect than Poland, i.e.: Estonia, the Czech Republic and Lithuania.

In contrast, Slovenia and Hungary, which on the one hand, have higher R&D expenditures than Poland, on the other hand, allocate relatively less funding to research conducted by the higher education sector. In Hungary, R&D expenditures are higher than in Poland

in relation to GDP (1.21% in 2016), but the share of funding for R&D activity conducted by universities is relatively low and has been gradually decreasing (from 0.23% of GDP in 2010 to 0.13% of GDP in 2016). There are similar trends also in Slovenia. In both countries, the enterprise sector plays a dominant role in conducting R&D and its share has been systematically increasing, weakening importance of the higher education sector (Fig. 1). In the Czech Republic and Estonia, which are also ahead of Poland in terms of expenditure on R&D in relation to GDP, the importance of the enterprise sector is also increasing, but the role of higher education in conducting research has been also strengthening, with the decreasing share of the government sector. In Poland, the share of the higher education sector in R&D was rather stable in the period 2010–2016 standing at around 0.3% of GDP, whereas the share of the enterprise sector gradually increased with the weakening importance of the government sector.

Conducting scientific research requires not only financial resources, but also people – talented scientists and researchers. In the period of 2010–2016, the number of scientists and engineers as a percentage of the economically active population aged 25–64 has been increasing gradually from 5.7% in 2010 to 7.0% in 2016. Nevertheless, the indicator was in 2016 still below the EU average (7.4%), but above the results achieved by most EU countries in the CEE region. This demonstrates the relatively large potential for creativity in Poland compared to most EU countries from the CEE (at least when it comes to the quantitative side of this phenomenon), however, one should remember that creativity is a human attribute, and the number of researchers is only a proxy. Slovenia is the leader in this respect in the CEE region.

The results of scientific activities include scientific publications, patents, trademarks and utility models. Available statistical data capture these on as an aggregate for the whole country, which gives only a rough picture of the activity of universities. However, these aggregate indicators can be compared for individual countries in order to capture Poland's position in terms of results of scientific activities. All countries of the CEE significantly deviate from the average UE28 terms of the proportion of scientific publications among the 10% most cited publications worldwide. Poland, with a score lower than half the EU average, is ahead of only four CEE countries (i.e. Bulgaria, Lithuania, Latvia, Croatia) in this category [7, 8].

Comparative analysis of creativity based on patent statistics confirms this conclusion. All CEE countries present relatively low patenting activity in the international procedure (PCT). In 2011–2016 the number of patent applications per 1 billion of GDP (in PPS) was significantly lower in the CEE than the EU average. For example, the average EU indicator in 2016 was more than six times higher than this indicator for Poland, two and a half times higher than in Hungary and more than fifteen times higher than in Romania [6].

Some of the CEE countries achieved slightly better results in terms of trademark applications and utility models. Estonia, Slovenia and Bulgaria stand out in the first of these categories. Bulgaria and Poland are the leaders in the CEE group in terms of utility model applications [6]. These results show that Poland's creativity is revealed in the area of design, rather than creating new solutions that can be patented on a global scale.

These general data for the whole economy can be supplemented by indicating universities, which in recent years have filed the most PCT patent applications. According

to the World Intellectual Property Organization (WIPO), in 2015–2017 the most active universities in Poland in terms of patenting were: Jagiellonian University, Rzeszów University of Technology, University of Warsaw and Wrocław University of Technology [33].

A picture of the universities' creativity can be obtained by analyzing the data published by the Innovation Policy Platform on patent applications filed at 5 key patent offices (so called patent families) in the world, i.e. the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the National Intellectual Property Administration of the People's Republic of China (CNIPA) and the United States Patent and Trademark Office (USPTO) [34]. Although the data is incomplete, it presents a very positive picture of patent activities by Polish universities and thus confirming creativity of Polish inventors. The percentage of patent applications from universities and research institutions is the highest in Poland among the CEE countries, and since 2003 it has more than doubled (from 18% to 41% of all applications). It can therefore be assumed that Polish scientists are more creative and willing to patent their ideas than researchers from other CEE countries. However, due to the limited availability of detailed data, this hypothesis requires further study.

Reflections on the position of Polish universities in terms of scientific research can be summarized by indicating the location of the best universities in the EU. Research of 1,337 universities from around the world, based on indicators such as: the number of scientific publications, the number of citations, average values of the Hirsch index of scientific employees, commitment to international scientific cooperation, show that 273 European universities successfully compete internationally. Most of these universities are in the United Kingdom (53 universities), Germany (43), Spain (30), Italy (29) and France (26) [35]. Only 8 universities from the CEE region reached the top of the ranking - three from Poland, two from the Czech Republic and one from Estonia, Romania and Slovenia. Polish universities can compete effectively only in two fields of science, whereas the Czech Republic, although they have two universities ranked among the top 30% in Europe, is able to compete effectively in three fields of science. The United Kingdom is the European leader in terms of tertiary education and scientific research excellence. 53 British universities competitive in 171 fields of science are included in 30% of the best universities in the world.

The analysis of indicators describing the creativity of Polish universities in comparison to other CEE countries presented above shows that Poland stands out in the CEE region in terms of scientific staff resources and a relatively high and stable share of the higher education sector in conducting R&D activities. However, this does not mirror the position of Polish universities when it comes to creativity measured by the number of citations of Polish authors or the number of patents. Some Poland's advantages with regards to creativity can be seen in industrial design.

4.2 Creativity and Education

The second area of universities activities closely related to creativity according to the concept of the "knowledge triangle" is education. What are the public expenditures on higher education? Is there a systematic increase in relation to GDP, which could suggest increasing support of the higher education sector? What percentage of the population has

a university degree? Can the Polish education system be considered open and friendly to students and doctoral students from abroad? Do Poles care about developing creativity and innovative by completing further training programs (lifelong learning)?

Poland stands out among other analyzed CEE countries by the highest and relatively stable public expenditure on higher education, reaching about 1.5% of GDP during the period considered. The EU28 average in the same period was by half lower (0.8% in the years 2010–2015, 0.7% in 2015). In the group of EU countries from Central and Eastern Europe, expenditure at a similar level to Poland can be observed in Estonia, but in this country a downward trend is visible, which was not recorded in Poland. Other analyzed countries have relatively stable public expenditure on higher education, in general higher than the EU28 average but lower than Poland.

The results of the scientific activities of the universities can be analyzed considering, among others, number and quality of scientific publications, research commercialization and educational activities, i.e. successful talents training. In order to measure educational activities of universities it is worth considering the percentage of people who completed tertiary education. Poland's position in this area is relatively good compared to other EU countries from the CEE and also compared to the EU28 average. In 2010–2016 in Poland, the percentage of people aged 25–34 who completed university studies gradually increased from 37.1% in 2010 to 43.5% in 2016. Only Lithuania achieved a better result than Poland. Since 2013 this ratio in Lithuania has been over 50%. Countries that rank similarly to Poland include Slovenia (43% in 2016), Latvia (42.1% in 2016) and Estonia (41.2% in 2016). In all of the above-mentioned countries, the percentage of people aged 25–34 who completed higher education exceeded the EU28 average in 2016 by several percentage points (e.g. Poland by 5.3 p.p. and Estonia by 3.0 p.p.) [7, 8].

A way to improve creativity is to promote openness of the education system and attract talented students and PhD students from abroad. The research show that less successful countries in attracting international students and scientists may weaken their competitiveness in the long run [36]. One of the indicators of the countries' position in attracting talent from abroad is the share of foreign doctoral students in the total number of doctoral students in a given country. In 2010–2016, on average the percentage of foreign PhD students in EU28 remained stable (in 2010 it was 21.2% and in 2016 it was 21.0%). The EU Member States from the CEE that are the most attractive for foreign PhD students include: the Czech Republic, Estonia, Hungary, Latvia, Slovenia and Slovakia. In Poland, the percentage of foreign PhD students is very low (2.0% in 2016) and, moreover, it decreased compared to 2010.

The low degree of internationalization of higher education in Poland is also indicated by data on the share of foreign students at the graduate level in the total number of students. In 2014, they accounted for only 3% of all students, while on average in the OECD it was 12% [36].

Many countries have introduced in higher education new management methods, as well as marketing strategies adopted from business in order to increase the inflow of international students. Lithuania is a good example in this respect. An analysis of the case of Mykolas Romeris University has shown that such management innovations brought a steady flow of incoming international exchange students [37].

The relatively high percentage of people in Poland who have completed university studies does not translate into their willingness to continuous development of knowledge and skills and further education. Compared to the CEE countries, Poland is quite weak considering the population aged 25–64 competing training programs (lifelong learning). The percentage of such people in Poland amounted to 4.3% in 2010–2013, and from 2014 gradually decreased to a value of 3.7% in 2016. Out of the eleven countries surveyed, only four have a worse position in this respect than Poland (i.e. Croatia, Slovakia, Bulgaria and Romania). In the period of 2010–2016, the percentage of the population aged 25–64 competing training programs in EU28 was stable (10.7–10.8%) and almost three times higher than in Poland. Among the CEE countries, Estonia and Slovenia occupy a leading position, where this indicator in 2016 was 15.7% and 11.6% respectively.

The above presented analysis of indicators regarding the importance and attractiveness of higher education in the CEE countries shows that this region, and in particular Poland, stands out in terms of relatively high public expenditures on higher education in relation to GDP and the percentage of people aged 25–34 who completed tertiary education however, unlike EU28 citizens, a significant proportion of well-educated Poles is not interested in post-university development, in particular in participation in further training programs (lifelong learning). Nevertheless, Polish universities and scholars offer many interesting learning opportunities for people at different levels of education (e.g. [38]). Despite relatively high public expenditure on higher education, Poland is not very attractive to talented students and PhD students from abroad. Almost every fourth doctoral student in the EU is a foreigner, while in Poland only less than two out of hundred. The results presented above may suggest that actions taken in Poland aimed at stimulating higher education and creativity of universities in shaping educational programs tailored to societal and industrial needs are insufficient.

4.3 Interactions Between Research, Education and Innovation

The concept of the "knowledge triangle" indicates that interactions between research, education and innovation take place at the universities. They are implemented through cooperation of higher education institutions with enterprises with regards to scientific research, development of entrepreneurship and shaping competences in business [29]. How is this cooperation carried out in Poland? Is it sufficient to create talents and drive innovation? The level of funding for R&D activities of universities by private entities is one of its measures. In Poland, such funding has been very low for many years. Funds allocated by the private sector to finance research conducted by higher education institutions constitute only 0.01% of GDP, while the average indicator in EU28 is five times higher (two times higher in Hungary and Czech Republic, and in Lithuania up to seven times higher) [7].

The interaction of universities with business in the field of education can be measured by the percentage of employees with a university diploma. Poland has a relatively good position in this area compared to other EU countries from the CEE. In the period of 2010–2016, the share of employees aged 25–64 with higher education in the total number of employees systematically increased from 31.6% to 37.2% and exceeded in 2016 the EU28 average by almost 2 percentage points. Only three CEE countries, Estonia, Latvia and Slovenia, achieved a better result than Poland [7]. Educating future employees (and

employers) is undoubtedly one of the ways of knowledge transfer between universities and enterprises and Poland has the potential to affect such transfer and diffusion of knowledge.

However, one of the most effective channels of knowledge transfer between science and business are joint projects related to research and education. Statistical data showing the scale of this phenomenon come from surveys conducted under the Community Innovation Survey (CIS). It is a study on innovative activities in enterprises, taking into account the size of enterprises and their structure by industry, various types of innovations and many aspects of implementing innovations, such as goals, sources of innovation, public financing or R&D expenditure. The survey is carried out every two years throughout the European Union, EFTA countries and EU candidate countries [7].

In order to compare the involvement of universities and other higher education institutions in cooperation with enterprises and its changes in 2010–2016, data from the last four surveys within the Community Innovation Survey, i.e. CIS2010, CIS2012, CIS2014 and CIS2016 were compiled (Table 3). The data shows that in Poland the share of enterprises cooperating in innovation activities with universities or other higher education institutions was stable in 2010–2014 and oscillated around 10%. At the same time, the average indicator in the EU28 increased by 3 percentage points, reaching 13.2% in 2014. In 2016, almost all analyzed countries from the CEE region reported a decrease in cooperation between enterprises and universities or other higher education institutions. The reverse trend is only observed in Bulgaria, Latvia and Lithuania. Comparing Poland with other countries of the CEE region, it can be seen that in 2016 the activity of universities and enterprises in cooperating for innovation is not very high. Only Romania had weaker results than Poland (Table 3).

Table 3. Share of enterprises cooperating in innovation activities with universities or other higher education institutions (%). Source: own elaboration based on [7]

	2010	2012	2014	2016
EU28	10.8	13.0	13.2	9
Bulgaria	6.7	4.5	3.9	6
Croatia	12.0	14.7	8.0	5.8
Czech Republic	14.6	14.6	12.2	5.4
Estonia	8.8	10.8	14.6	11.5
Hungary	21.4	18.1	12.3	5.7
Latvia	9.8	7.7	7.3	7.9
Lithuania	11.3	18.9	8.0	10
Poland	**10.8**	**10.5**	**10.6**	**5.2**
Romania	6.4	4.9	12.2	3.4
Slovenia	22.0	25.4	19.9	13.6
Slovakia	13.6	12.7	12.8	11.8

Conclusions from the above analysis of creativity as an effect of interactions between research, education and innovation can be supplemented with a comparison of a synthetic indicator of countries' potential to be part of global education, innovation and research network, which consists of the following three components [36]:

- funding incentives for international co-operation,
- foreign/international students and high-skilled workers,
- international co-operation in research.

Scientific research co-operation between institutions from different countries in terms of joint publications or patent cooperation, streamlines networking and increases the likelihood that research will be applied by the enterprise sector [39]. Global educational networks are just as important as collaboration in innovation and research. Increasing competition is visible when it comes to talent acquisition, as the influx of foreign students increases the possibilities of knowledge diffusion. Knowledge can spread faster, because interpersonal relationships create new learning opportunities that go beyond the exchange of codified information [36]. For this reason, financial incentives for higher education institutions aimed at encouraging research and teaching internationalization are increasingly important.

Comparison of a synthetic indicator of countries' potential to be part of global education, innovation and research network among analyzed CEE countries reveals relatively small potential of Poland [35]. All components of this synthetic indicator (i.e. international cooperation in research, foreign/international students and high-skilled workers, funding incentives for international cooperation) have the lowest values for Poland among the analyzed group of countries. The leaders in the CEE region are Hungary and the Czech Republic, with indicators higher than the OECD average [35].

This result may indicate that the effects of interactions between research, education and innovative entrepreneurship in Poland are insufficient to stimulate the creativity of innovation system actors. To improve the efficiency of the knowledge triangle, support of this type of interactions within universities and between universities and enterprises is required.

5 Conclusion

The review of scientific literature presented in this study confirms that innovation is the result of human creative activity, while creativity is influenced by, among others quality of research and education, and mainly university-level education. This empirical observation has set the objective of this study, which is to identify the position of Polish universities in terms of creativity compared to other EU countries, in particular those from CEE.

A comparative analysis of a number of indicators characterizing the potential of Polish universities in the field of creativity showed that Poland stands out in the CEE region in terms of the relatively high share of the higher education sector in conducting scientific research and the availability of scientific staff resources. However, this does not translate into the leading position of Polish universities in the CEE region when it

comes to creativity measured by citations of Polish authors' publications, or the number of patents filed by inventors. Poland's advantages in terms of creativity over analyzed CEE countries are only visible in industrial design - this is confirmed, among others, by higher than average in the EU and one of the highest in the region number of applied utility models in relation to GDP. However, this does not change the fact that the effects of the interaction within the "knowledge triangle" in Poland between research, education and innovative entrepreneurship are insufficient to stimulate creativity and broaden the involvement of national actors in global research and innovation networks.

Chances to change Poland's position described above are seen in the OECD research results on readiness to learn and creative thinking. The synthetic indicator constructed by the OECD is based on six factors related to openness to new experiences and creative thinking. Source data for calculating the indicator of readiness to learn and creative thinking were collected in the Survey of Adult Skills (PIAAC) questionnaire in June 2017, which covered 23 countries, including 6 EU countries from Central and Eastern Europe. OECD research shows that Poles are a creative nation compared to other CEE countries. Unfortunately, the OECD study did not cover all the CEE countries analyzed in this article (the index for Hungary, Latvia, Romania, Bulgaria, Croatia was not calculated). Thus, broader comparison of Poland's position with all the countries of the CEE region is not possible. However, among the six CEE countries covered by the OECD survey, Poland was ranked second (behind Slovakia) in terms of readiness to learn and creativity. Interestingly, the Czech Republic, which is in general performing better than Poland in terms of innovativeness of the economy and is ranked higher than Poland in the European Innovation Scoreboard [6], is in the light of OECD research a less creative nation [36].

Activation of the creativity potential of Polish universities requires stronger support for strengthening interactions within the "knowledge triangle", both locally and internationally. When developing an innovation policy, keep in mind that research, education, and innovation activities have all become more globalized as a result of the globalization of production processes. Nowadays, countries compete not only for physical capital, but also for talents. However, talent development is not possible without wider international cooperation in research, science, education and production processes. Cooperation in all of its forms (national, international, intersectoral) is a source of inspiration for creativity and a means of better utilizing local resources to generate new ideas. Polish universities should work towards strengthening this cooperation.

Last, but not least, there are research limitations that should be taken into account. Main limitations concern the dataset – its small size, data availability and completeness as well as sample, which encompasses only entire countries, neither regions nor individual universities. Moreover, while interpreting the research results the selection of indications should be also considered.

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