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THE REGIONAL DIFFERENTIATION OF KNOWLEDGE POTENTIAL IN POLAND IN THE CONTEXT OF BUILDING A KNOWLEDGE-BASED ECONOMY

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ABSTRACT

The aim of this study was to evaluate the regional differentiation of knowledge potential in Poland and changes which have occurred in this field between 2009 and 2015. The study was based on numerical taxonomy methods, including the linear ordering method. It was concluded that the regional differentiation in knowledge potential in Poland is at a moderate level, and the scale of this differentiation has decreased. This finding has been confirmed by the value of the variability coefficient, which decreased from 22% in 2009 to 17.5% in 2015. The highest level of knowledge potential was identified in Mazowieckie Province. The lowest level of knowledge potential was noted in Lubuskie, Świętokrzyskie and Warmińsko-Mazurskie Provinces.

Key words: knowledge potential, synthetic knowledge index, regional differentiation

INTRODUCTION

The contemporary economy is referred to as the knowledge-based economy (KBE). Its most important resource and a development stimulant is knowledge, and the ability to create, absorb and implement knowledge. The KBE development is stimulated by high quality human capital, which is 'a carrier' of knowledge and innovation, and modern information and communication technologies, which enable the dissemination and processing of information and knowledge. An important role in the growth of the knowledge-based economy is played by research and development activities as well as the quality of an institutional environment.

Using terminology adopted by the World Bank, it can be presumed that the contemporary economy rests on four pillars: an educated and qualified population, effective innovation systems, modern and adequate information infrastructure, and a system of economic and institutional incentives. The cohesive development of these areas are fundamental to the process of creating a knowledge-based economy in a given country. The regional dimension of the KBE formation is extremely important. The creation of KBE in a country is based on regions possessing high potential and the ability to develop each of the KBE pillars.

The aim of this study was to evaluate the regional differentiation of knowledge potential in Poland, and the changes which have occurred in this field between 2009 and 2015. The following research hypothesis was formulated: "The regional differentiation of knowledge potential in Poland is at a moderate level and the scale of this differentiation is decreasing".

The study was conducted on the NUTS II level. Taxonomy methods were applied, including a linear ordering method based on a synthetic variable and a method of clustering linearly ordered objects.

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THE CONCEPT OF A KNOWLEDGE-BASED ECONOMY

The 1990s witnessed a growing interest in knowledge and its influence on economic processes. Knowledge was considered to be the most essential resource – more important than land, capital or labour [Drucker 1998, Dunning 2000]. To highlight this new paradigm of growth, driven by knowledge and innovation, the concept of a knowledge-based economy was introduced to economic sciences [Kukliński 2001, 2007].

The notion of a knowledge-based economy is not defined unequivocally. Different authors underline different aspects of this phenomenon. One group of definitions emphasises the role of knowledge in the development of this type of economy. In this approach, the knowledge-based economy is defined as an economy which directly depends on the production, distribution and implementation of knowledge and information [OECD 1996], as an economy in which knowledge is efficiently created, absorbed, transferred and implemented by enterprises, organisations, physical persons and communities, stimulating a rapid growth of the economy and society [Dahlman and Andersson 2000]. It is an economy which uses knowledge as its main motor of economic growth [Gorji and Alipourian 2011], or it is an economy in which there are many enterprises that build their competitive advantage on knowledge [Koźmiński 2001].

Another group of definitions underlines the role of innovation in the development of the KBE. Gorzelak and Olechnicka [2003]point to the fact that the essence of the knowledge-based economy is the high intensity of using in practice new elements of knowledge, such as innovations. Piech [2007] defines the KBE as an economic system powered by innovations, which by influencing all branches of the economy accelerates the increase in productivity and the rate of economic growth. Czyż [2009] underlines that the base for this type of economy is composed of R&D activities and innovations, which lead to the modernisation of the economy and improved productivity.

The third group of definitions places an emphasis on the role of information and communication technologies (ICT) in the development of the KBE. Żelazny [2006] points to the fact that in the knowledge-based economy there is a process of dynamic development driven by information and telecommunication technologies as well as knowledge resources, which are mutually dependent. Al-Busaidi [2014] stressed that the base of the knowledge economy and a necessary condition for its development consists of ICT, which significantly support the development of the other pillars of knowledge. Bashir [2013] defines the KBE as an economy characterised by the high and growing intensity of the implementation of ICT by well-educated employees. In fact, individual definitions of the knowledge-based economy highlight its different pillars, which have been described in the knowledge assessment methodology (KAM), developed by the World Bank in 1998. The said pillars are [Chen and Dahlman 2006, Ujwary-Gil 2013, World Bank 2016]:

1. Economic incentive and institutional regime[1], which encourages effective entrepreneurship, enables efficient allocation of resources and motivates for effective creation, dissemination and implementation of knowledge; the variables which describe this pillar refer to legal regulations in a given country, the quality of these regulations and barriers used in trade policy.
2. Educated and skilled workers[2], who can constantly develop and adjust their skills for the sake of efficient creation and implementation of knowledge; the variables used to describe this pillar include: high adult literacy rate, enrolment to secondary

[1] In the literature this pillar is also known as the system of economic incentives [cf. Strożek 2012], institutional and regulatory regime [cf. Nowak 2013]. Importantly, the use of different terminology with respect to a given KBE pillar is often connected with the adopted methodology of research and selection of variables describing a given KBE pillar.

[2] This pillar is also called the human capital pillar, but then it is equated with its narrow sense, where it is understood as the level of education of the society in economy [Florczak 2008, Niklewicz-Pijaczyńska and Wachowska 2012], as education capital in the quantitative sense [Soszyńska 2013]. In a broad approach, human capital corresponds to the resources of knowledge, skills, competences, health and even vital energy of a society [Przybyszewski 2007, Peters 2013].

and higher education schools, net enrolment rate, share of allocated resources to education in GDP, number of higher education students in an entire population.

3. Effective innovation system[3] comprising enterprises, research centres, universities and other organisations, which are able to draw on the growing resources of global knowledge, assimilate it and adjust it to local needs; the innovation indicators include: number of employees in the R&D sector, inputs in R&D as % of GDP, number of scientific publications, number of patents.
4. Modern and adequate information infrastructure, which facilitates effective communication, dissemination and processing of information and knowledge; the level of this infrastructure is measures, i.a., by the number of telephones, computers and Internet users per 1,000 persons, the level of expenditure on ICT expressed in % of GDP, and the accessibility to e-administration.

The knowledge assessment methodology is constantly improved and currently is based on 148 variables[4], which represent the four pillars of KBE. Within the KAM methodology, two simplified indices have also been determined [Chen and Dahlman 2006, Wasiak 2008, Bashir 2013]:

- knowledge index (KI) – composed of nine variables, three for each of the three pillars (except the system of economic and institutional incentives);
- knowledge economy index (KEI) – composed of 14 variables, including three for each of the four pillars and two variables describing the economic condition of the country.

The knowledge index is a measure that determines the creation, use and diffusion of knowledge, which is the knowledge potential in a given economy. The knowledge economy index, in turn, serves to make economic comparisons on international and temporal scales [Tocan 2012, Nowak 2013].

RESEARCH METHODOLOGY

The synthetic index was used to assess the potential of knowledge in the regions. The index was built in accordance with the construction of the KI, but some modifications were introduced[5]. The selection of variables was based on formal and substantial criteria, which led to the choice of 36 variables. Statistical aspects were also taken into consideration, i.e. the variability of the variables and their degree of correlation with other variables. Eventually, 25 variables were included in the set of variables to describe the knowledge potential in regions, and these were divided between three KBE pillars:

1. Human capital:
   - X_1 – net enrolment rate in lower-secondary vocational schools,
   - X_2 – net enrolment rate in secondary comprehensive schools,
   - X_3 – number of students in higher education schools per 10,000 of the population,
   - X_4 – number of higher education schools per 1 million of the population,
   - X_5 – number of students in post-university studies per 10,000 of the population,
   - X_6 – number of PhD students per 10,000 of the population,
   - X_7 – number of children and adolescents doing compulsory English language learning in primary, secondary and post-secondary schools per 1,000 of the population,
   - X_8 – percentage of the population aged 15–64 years with higher education,
   - X_9 – percentage of adults aged 25–64 years participating in education or training,
   - X_{10} – expenditure on education and upbringing expressed as % of GDP.

[3] This pillar is also called the efficient system of innovations [cf. Strożek 2012] or system of innovations [cf. Nowak 2013].

[4] Such a large number of variables means that among the disadvantages of the KAM method researchers mention the doubling of many data due to the inclusion of strongly correlated variables.

[5] In the literature, many studies can be found in which the methodology of KAM is modified [cf.: Chojnicki and Czyż 2003, Kukliński and Burzyński 2004, Piech 2006, Strahl 2009, Dworak et al. 2014].

2. Innovation system:
   - X_{11} – number of units where R&D activities are undertaken per 10,000 national economy business units listed in the REGON register,
   - X_{12} – level of internal inputs into R&D per capita,
   - X_{13} – number of persons employed in the R&D sector in full time equivalents (FTE) per 1,000 occupationally active persons,
   - X_{14} – percentage of industrial enterprises which have made inputs into innovation,
   - X_{15} – share of net revenue from sale of innovative products in industrial enterprises, in the net revenues from total sale,
   - X_{16} – patents granted by the patent Office of the Polish Republic, per 1 million of the population,
   - X_{17} – share of human resources dedicated to science and technology among the occupationally active population,
   - X_{18} – percentage of students doing technical or natural science studies.
3. Information and communication technology (ICT):
   - X_{19} – percentage of households having personal computers with access to the Internet,
   - X_{20} – percentage of households having mobile telephones,
   - X_{21} – percentage of households having devices for receiving satellite or cable television programmes,
   - X_{22} – percentage of enterprises[6] using computers,
   - X_{23} – percentage of enterprises[6] having access to the Internet,
   - X_{24} – percentage of enterprises[6] having own webpage,
   - X_{25} – percentage of enterprises[6] using the Internet in contacts with public administration.

A synthetic measure was determined for each KBE pillar. Appropriate variables were turned into a synthetic index using non-formula methods, which consist of an operation of averaging values of normalised variables. Normalisation of variables was accomplished through the procedure of zeroed unitarisation. In order to ensure the comparability of Polish provinces between the years, the variables expressed in monetary units were given in constant prices of 2015, and all variables were treated as panel data. Due to the fact that all variables were ascribed the character of a stimulant[7], the procedure of unitarisation was conducted according to the following formula [Panek and Zwierzchowski 2013]:

$$z_{ij} = \frac{x_{ij} - \min_i\{x_{ij}\}}{\max_i\{x_{ij}\} - \min_i\{x_{ij}\}} \tag{1}$$

where:
z_{ij} – normalised value of j-th variable in i-th object;
x_{ij} – value of j-th variable in i-th object;
$\min_i\{x_{ij}\}$, $\max_i\{x_{ij}\}$ – min and max values of j-th variable in the set of objects.

Normalised variables were submitted to the synthetisation procedure, according to the following aggregation formula [Panek and Zwierzchowski 2013]:

$$s_i = \frac{1}{m}\sum_{j=1}^{m} z_{ij} \quad i = 1, 2, ..., n \tag{2}$$

where:
s_i – value of the synthetic variable in i-th object;
z_{ij} – normalised value of j-th variable in i-th object;
m – number of variables.

Based on values of the synthetic variables determined for the individual KBE pillars, a synthetic knowledge index, which determines the general knowledge potential in the Polish provinces, was computed. This index was calculated as an arithmetic mean of the partial indices determined for the three KBE pillars.

[6] This concerns enterprises of the non-financial sector.
[7] The character of variables was identified on the basis of content-related indications. The presumed character of variables was verified ex post, by testing the correlation of individual variables with the synthetic variable.

REGIONAL DIFFERENTIATION OF KNOWLEDGE POTENTIAL IN POLAND

The value of the synthetic knowledge index for the total of Polish provinces increased over the analysed time period by over 40%. The dynamics of the growth of the synthetic knowledge index in particular provinces was varied (Table 1).

The highest dynamics occurred in the Lubuskie Province – 1.79 and Podlaskie Province – 1.62, while the lowest dynamics appeared in the Pomorskie and Zachodniopomorskie Provinces – at 1.29 for both.

Importantly, during the entire time period analysed, the regional differentiation of knowledge potential in Poland remained at a moderate level[8], and the scale of differences, comparing the years 2009 and 2015, diminished slightly. This can be confirmed by the value of the variability coefficient, which decreased from 22% in 2009 to 17.5% in 2015. In addition, this conclusion can be supported by the fact that the ratio of the lowest synthetic value of the knowledge index to

Table 1. Synthetic knowledge index in Polish provinces in the years 2009–2015

Province	Value of the synthetic knowledge index							Dynamics of changes 2009–2015
	2009	2010	2011	2012	2013	2014	2015	
Dolnośląskie	0.395	0.475	0.495	0.533	0.522	0.587	0.603	1.52
Kujawsko-Pomorskie	0.323	0.442	0.425	0.435	0.390	0.409	0.445	1.38
Lubelskie	0.317	0.405	0.460	0.470	0.484	0.491	0.488	1.54
Lubuskie	0.222	0.350	0.338	0.344	0.373	0.387	0.396	1.79
Łódzkie	0.311	0.412	0.395	0.432	0.436	0.442	0.465	1.50
Małopolskie	0.408	0.518	0.517	0.514	0.525	0.556	0.575	1.41
Mazowieckie	0.557	0.635	0.634	0.666	0.690	0.722	0.739	1.33
Opolskie	0.334	0.402	0.394	0.434	0.411	0.437	0.448	1.34
Podkarpackie	0.341	0.422	0.408	0.399	0.434	0.481	0.504	1.48
Podlaskie	0.267	0.382	0.393	0.424	0.405	0.398	0.433	1.62
Pomorskie	0.483	0.570	0.547	0.555	0.550	0.602	0.622	1.29
Śląskie	0.397	0.483	0.472	0.507	0.500	0.519	0.519	1.31
Świętokrzyskie	0.251	0.331	0.291	0.353	0.349	0.368	0.399	1.59
Warmińsko-Mazurskie	0.259	0.379	0.347	0.329	0.352	0.368	0.382	1.48
Wielkopolskie	0.361	0.450	0.453	0.457	0.485	0.505	0.516	1.43
Zachodniopomorskie	0.320	0.425	0.402	0.398	0.387	0.399	0.414	1.29
×	Variability coefficient (%)							×
	22.0	16.3	17.7	17.4	17.6	18.4	17.5	

Source: Own calculations, based on data from the Local Data Bank of the Polish Central Statistical Office and from Eurostat.

[8] It was assumed that a value of the variability coefficient below 10% means insignificant variability, within the interval <10%; 40%> – moderate variability, and over 40% – high variability of the characteristic.

its highest value in a given year declined from 2.51 in 2009 to 1.93 in 2015.

As a result of the differentiated level of the synthetic knowledge index at the onset of the analysed time period and the varied dynamics of its growth over the same period, the situation of particular provinces relative to the others changed significantly. This can be confirmed by ranking lists made according to the synthetic knowledge index values and the results of the clustering of provinces supported by the standard deviation method (Table 2). In line with the assumptions of this method, the set of analysed objects was divided into four groups, and the borderlines between the intervals were set up based on the values of an arithmetic mean of the synthetic knowledge index for the total of provinces ($\bar{s}$) and the level of standard deviation of this index $S(s)$ in the analysed year [Panek and Zwierzchowski 2013].

The unquestionable leader with respect to knowledge potential is the Mazowieckie Province, which occupied the first place over the entire analysed time period. The value of the synthetic knowledge index in this province at the beginning of the study was at such a high level that most of the other provinces were unable to reach it even six years later. In fact, only three provinces managed to achieve it, and these were the Dolnośląskie and Pomorskie Provinces in 2014, and the Małopolskie Province in 2015. An asset of the Mazowieckie Province is its very high potential of knowledge in all of the three KBE pillars. This province is

Table 2. Results of the linear ordering and clustering of the provinces with respect to knowledge potential in 2009 and in 2015

2009			2015		
Ranking position	Province	knowledge potential	Ranking position	Province	knowledge potential
1	Mazowieckie	very high $s_i \geq \bar{s} + S(s)$ $s_i = 0.434$	1	Mazowieckie	very high $s_i \geq \bar{s} + S(s)$ $s_i \geq 0.594$
2	Pomorskie		2	Pomorskie	
3	Małopolskie	high $\bar{s} + S(s) > s_i \geq \bar{s}$ $0.434 > s_i \geq 0.347$	3	Dolnośląskie	
4	Śląskie		4	Małopolskie	high $\bar{s} + S(s) > s_i \geq \bar{s}$ $0.594 > s_i \geq 0.497$
5	Dolnośląskie		5	Śląskie	
6	Wielkopolskie		6	Wielkopolskie	
7	Podkarpackie	low $\bar{s} > s_i \geq \bar{s} - S(s)$ $0.347 > s_i \geq 0.260$	7	Podkarpackie	
8	Opolskie		8	Lubelskie	low $\bar{s} > s_i \geq \bar{s} - S(s)$ $0.400 > s_i \geq 0.497$
9	Kujawsko-Pomorskie		9	Łódzkie	
10	Zachodniopomorskie		10	Opolskie	
11	Lubelskie		11	Kujawsko-Pomorskie	
12	Łódzkie		12	Podlaskie	
13	Podlaskie		13	Zachodniopomorskie	
14	Warmińsko-Mazurskie	very low $s_i < \bar{s} - S(s)$ $s_i < 0.260$	14	Świętokrzyskie	very low $s_i < \bar{s} - S(s)$ $s_i < 0.400$
15	Świętokrzyskie		15	Lubuskie	
16	Lubuskie		16	Warmińsko-Mazurskie	

Source: The author, based on the data included in Table 1.

the Polish leader with respect to the level of human capital and innovation systems; it also occupies the second position in Poland regarding the development of ICT.

The Pomorskie Province occupies the second place in Poland with respect to knowledge potential. This province is Poland's leader in terms of the level of development of ICT. It is characterised by a high potential in the field of human resources. The Dolnośląskie Province scores high in the ranking list. It moved from the 5th place in 2009 to the 3rd place in 2015, and together with the Mazowieckie and Pomorskie Provinces, it was classified as belonging to the group of provinces with a very high knowledge potential. The strength of the Dolnośląskie Province lies in its well-developed information and communication infrastructure and high potential in the field of innovations.

The worst situation with respect to knowledge potential appears in the Lubuskie, Świętokrzyskie and Warmińsko-Mazurskie Provinces. During the entire time period studied, these provinces belonged to the group of provinces with very low knowledge potential. The Lubuskie Province, despite having a relatively good situation in the realm of ICT, occupied the last place in the other two areas of knowledge. The Świętokrzyskie Province is characterised by having a very low knowledge potential in the innovation system and in ICT. The weakness of the Warmińsko-Mazurskie Province lies in its very low knowledge potential in all of the pillars. Noteworthy, however, is the fact that the situation of all these provinces, compared to the country's average, improved. In 2009, the value of the synthetic knowledge index in the Lubuskie Province was lower than the country's average value by as much as 36%, whereas in 2015 the difference decreased to 20.3%. The analogous results for the Świętokrzyskie Province were 27.7% in 2009 and 19.7% in 2015, while in the Warmińsko-Mazurskie Province the figures were 25.4% in 2009 and 23.1% in 2015.

While analysing the ranking lists of Polish provinces, attention was drawn to the fact that the strength of individual provinces stems from different aspects of knowledge. It is therefore worth analysing which of the KBE pillars is the leading pillar in most provinces, and within which pillar can the highest knowledge potential be observed (the figure).

In 2009, the leading pillar in 10 provinces was human capital, while ICT played this role in the remaining six provinces. Thus, the provinces were characterised by a relatively high level of education of the population, which is a necessary condition for efficient creation, acquisition, dissemination and application of

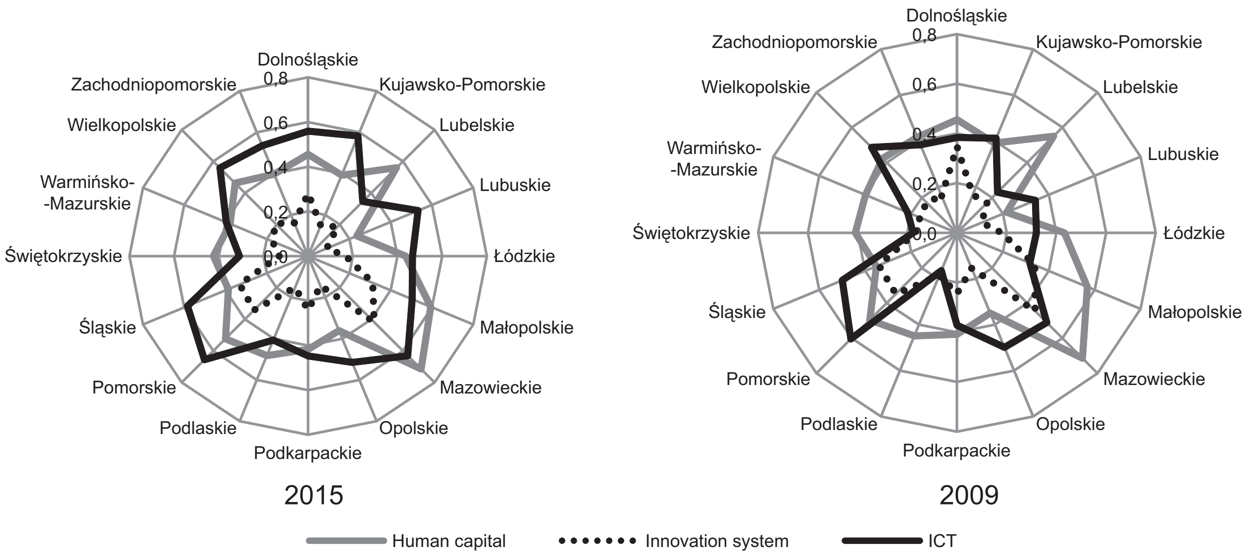

Fig. Knowledge potential in the Polish provinces in individual KBE pillars, in 2009 and 2015
Source: The author, based on data obtained from the Local Data Bank and from Eurostat.

knowledge; as well as a relatively high provision of ICT, which facilitate effective communication, dissemination of knowledge and the processing of information and knowledge. The knowledge potential in the sphere of innovations was relatively low. In the consecutive years, the provinces noted considerable improvement in the area of ICT and innovation systems, which has been confirmed by the values of synthetic indices determined for the particular KBE pillars and the dynamics of their change. Consequently, in 2015, the leading pillar in 15 provinces was the ICT pillar, and in seven provinces the second most important pillar was that of the innovation system. It was only in the Małopolskie Province that the leading pillar was the innovation system.

CONCLUSIONS

The development of a knowledge-based economy in Poland requires coherent regional actions to strengthen its four pillars. The national KBE can be built on well-developed regions with a high potential of knowledge in its particular pillars. This study has evaluated the regional differentiation of knowledge potential in Poland and the changes that have occurred in this context from 2009–2015. In order to assess the potential of knowledge, a synthetic knowledge index was applied, whose construction referred to the KI, developed and used by the World Bank, to measure the potential of knowledge in a given economy.

The results of the analyses can be summarised as follows. During the time period analysed, a greater than 40% increase in the value of the synthetic knowledge index in Poland was recorded, although the dynamics of changes in the values of this index varied highly in the regional approach. The highest growth dynamics were noted in the Lubuskie Province – 1.79 and Podlaskie Province – 1.62, while the lowest growth dynamics were in the Pomorskie and Zachodniopomorskie Provinces – at 1.29 in each. As a consequence of such regionally varied dynamics in the growth of the synthetic knowledge index in Poland and despite significant differences in the level of this index at the beginning of the analysed period of time, the structure of the total assemblage of Polish provinces with respect to knowledge potential became more homogeneous. The scale of regional differentiation of the knowledge potential still remains at a moderate level. This is confirmed, for example, by the value of the variability coefficient, which decreased from 22% in 2009 to 17.5% in 2015. The research hypothesis, which presumed that the regional differentiation of the knowledge potential in Poland is at a moderate level and the scale of this differentiation is decreasing, was positively verified.

The leader in knowledge potential in Poland is the Mazowieckie Province. High positions are also occupied by the Pomorskie, Dolnośląskie and Małopolskie Provinces. The lowest knowledge potential was determined in the Lubuskie, Świętokrzyskie and Warmińsko-Mazurskie Provinces. Regardless of the increase in the value of the synthetic knowledge index over the time period analysed, the provinces still have a very low knowledge potential.

The Polish provinces are characterised by a variable level of knowledge potential in the particular KBE pillars. Significantly, an increase in knowledge potential was noted within the information and communication infrastructure. This pillar became the leading one in as many as 15 provinces in 2015. From the point of view of building a knowledge-based economy, this is very important. ICT is the key infrastructure in a knowledge-based economy, and it is a driving force. The widespread use of ICT contributes to an increased efficiency of individual economic entities and creates opportunities for the improvement of the entire economy. Hence, ITC is a very important aspect of building a knowledge-based economy and developing an information society. A considerable increase in knowledge potential was also recorded in the sphere of innovation systems, which means that companies, research centres, universities and other institutions which compose this system are able to use the existing knowledge resources more effectively and transform them into innovations, which is also extremely important in the context of forming a knowledge-based economy.

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REGIONALNE ZRÓŻNICOWANIE POTENCJAŁU WIEDZY W POLSCE W KONTEKŚCIE BUDOWANIA GOSPODARKI OPARTEJ NA WIEDZY

STRESZCZENIE

Celem badań była ocena regionalnego zróżnicowania potencjału wiedzy w Polsce oraz zmian, jakie zaszły w tym zakresie w latach 2009–2015. Badania przeprowadzono przy wykorzystaniu metod taksonomii numerycznej, w tym metody porządkowania liniowego. Na podstawie przeprowadzonych analiz stwierdzono, iż regionalne zróżnicowanie potencjału wiedzy w Polsce kształtuje się na poziomie średnim, a skala tego zróżnicowania się zmniejszyła. Potwierdzeniem tego jest wartość współczynnika zmienności, która obniżyła się z poziomu 22% w 2009 do 17,5% w 2015 roku. Największym potencjałem wiedzy charakteryzuje się województwo mazowieckie, a najmniejszy potencjał wiedzy występuje w województwach lubuskim, świętokrzyskim i warmińsko-mazurskim.

Słowa kluczowe: potencjał wiedzy, syntetyczny wskaźnik wiedzy, regionalne zróżnicowanie