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**AN ATTEMPT TO MEASURE A KNOWLEDGE-BASED ECONOMY  
ON THE EXAMPLE OF SPATIAL DIVERSITY OF POLAND'S VOIVODESHIPS  
IN 2009-2016**

*PRÓBA POMIARU SPOŁECZEŃSTWA OPARTEGO NA WIEDZY W POLSCE NA PRZYKŁADZIE  
ZRÓŻNICOWANIA PRZESTRZENNEGO WOJEWÓDZTW W LATACH 2009-2016*

**Key words: knowledge-based economy, spatial diversity, TOPSIS, ranking of voivodeships**

*Słowa kluczowe: gospodarka oparta na wiedzy, przestrzenne zróżnicowanie, TOPSIS, ranking województw*

*JEL codes: O31, O32, O43*

**Abstract.** The aim of the article is an attempt to measure the level of development of a Knowledge-Based Economy (KBE). The applied Knowledge Assessment Methodology (KAM), developed by the World Bank in 1999, is one of the methods for measuring the degree of development of KBE. It is connected with the development of a set of indicators describing the functioning of individual socio-economic dimensions, grouped into four categories: (A) economic and institutional, (B) education and human resources, (C) information systems and new technologies, (D) information technologies. The analysis of these pillars helps to gain a competitive advantage (region, industry, national economy). Synthetic indexes for Polish voivodeships in 2009-2016 were calculated. The research results present a significant spatial difference in the development of KBE. Changes in this diversification of voivodeships were presented for 2015 and 2016 in relation to 2012 and 2009.

## **Introduction**

The information society plays a significant role, among other spheres, in modern life. Its development has enabled the widespread use of information in the production of goods and services. A new paradigm has emerged in which knowledge, along with land, capital and labour, has become a new resource, supporting decision making on macro and micro scales. Changes in the technical and organizational development of telecommunication technologies have been successive since the end of the 20<sup>th</sup> century and have resulted in changes in: social, economic, and cultural spheres. What is more, practices applied by developed countries, basing on an exchange of information, ensuring a long-term increase in added value, have become widespread. Thus, these processes are focused around the effects of the impact of technical progress on economic growth, assigning a particular role to information and communication technologies.

At the same time, the society of mass production and consumption of material goods have transformed society, which is now characterized by an increase in the share of services in economic development. This is the result of an increase in the application of information and telecommunication technologies to the widespread use of information in production and the provision of services. As a result of this new form of information transfer, civilization changes have taken place.

The aim of this paper is an attempt to measure the Knowledge Based Economy with use of spatial diversity Poland's Voivodships in 2009-2016.

### **Knowledge-Based Economy measurement methodology**

The summary of the discussion in the 1990s, concerning KBE development, was a typology adopted by Frank Webster, including: technological, economic, professional, spatial and cultural approaches. Differences in approaches to the KBE concept have caused a lack of uniform characteristics that would ensure a satisfying understanding of the concept, thus creating: “measurement problems (...) which is the central reference for every definition worthy of acceptance (...) of a new type of society [Webster 2006, p. 21]. Nevertheless, a wide group of stakeholders interested in quantitative research of KBE was established. The area of research resulting from technological progress and characterizing ICT industry results has created a lack of concept unification influencing the number and content of generated indicators. This creates a difficult problem when monitoring the role of ICT in economic growth by standardizing these indicators by international institutions. Therefore, two concepts used to measure the level of KBE development were established, namely: structural and holistic [Roszkowska, Piotrowska 2011].

The holistic approach applied in this paper has generated a group of indicators describing the socio-economic perspective. This has led to the popularization of various models of KBE development, the substantive value of which greatly depends on the accuracy of selection and readability of indicators used. The large number of indicators has caused comparison to be impossible. This has resulted in an increase in popularity of complex indexes of KBE and simple interpretation. Synthetic indexes facilitate the interpretation of analysed results of socio-economic phenomena in the multidimensional space of variables, due to the replacement of a large set of features with one synthetic feature. This transition has been possible thanks to the aggregation of variables. This leads to the ordering of examined objects using values of an aggregate variable and making comparisons both in space and time. A relatively easy interpretation of synthetic indexes allows researchers to clearly present the ranking of the level of KBE development in regions and countries. Synthetic indexes perform increasingly important socio-economic functions, therefore, the following were involved in their creation: international and national institutions, commercial companies, social organizations and scientific units. Michał Goliński [2011, p. 212] quite rightly said that “synthetic indexes are burdened with subjective choices of their creators and often fail to explain phenomena related to KBE in more detail than individual partial indices. Their choice was determined by the availability of statistical data and, therefore, should play a complementary role in the area of research to formulate and make important political or investment decisions”.

The Knowledge Assessment Methodology (KAM) is one of the holistic methods for measuring the level of KBE development and is related to the development of a set of indicators describing the functioning of particular socio-economic dimensions. It was developed by the World Bank Institute in 1999. Under this method, KBE measurement was based on a set of indicators grouped into four categories:

- economic and institutional,
- education and human resources,
- information systems and new technologies,
- information technology.

In this study, pillars proposed in KAM have been analyzed [Roszkowska, Piotrowska 2011]. Synthetic indexes for Polish voivodeships in 2009-2016 were calculated. The selection of explanatory variables, based on KAM, was adapted to regional conditions depending on availability, reliability and completeness of statistical data on a regional basis.

On the basis of the explanatory variables mentioned above, values of partial indexes describing the level of each pillar development for voivodeships was calculated. Then, as an arithmetic average of partial indices, a generic synthetic KBE level meter for Polish voivodeships was calculated. This index, using the Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS), was used for the linear ordering of voivodeships according to the

researched KBE level. TOPSIS, a method of linear ordering of multi-feature objects proposed by Ching-Lai Hwang and Kwangsun Yoon [Hwang, Yoon 1981] and which has foundations in Hellwig's theory [Hellwig 1968, Hellwig 1997] was applied. It involves the determination of distance of each object from the positive ideal solution and the negative ideal solution and, then, ordering the objects on a line.

The first stage included statistical verification of simple features – indicators selected on the basis of substantive premises, in accordance with KAM. In order to eliminate overly correlated indicators, the correlation matrix of the value of indicators and the reverse matrix was analyzed. The analysis of the coefficient of variation allowed to reject features that were not significant from the point of view of linear ordering of voivodeships.

At the second stage, the indicators selected at the first stage were analyzed in terms of the correlation sign of these simple features with the constructed composite feature, i.e. in the case of a positive sign correlation, they were regarded as benefit criteria, in the case of a negative sign – cost criteria. All were transformed to the benefit criteria in order to facilitate comparability after which they were normalized.

The third stage was the calculation of geometric distance from the development of the positive ideal solution as well as the distance from the negative ideal solution for each voivodeship.

The fourth stage involved determining partial synthetic index values of four pillars of each voivodeship.

The previous four stages were carried out for each pillar: A, B, C and D separately. Then, in the fifth stage, the final value of the synthetic index of a Knowledge-Based Economy for voivodeships of Poland [OECD 1996] was calculated as the arithmetic mean of the partial measures of the four pillars. In the final, fifth stage, the voivodeships of Poland were linearly arranged and classified based on a statistical criterion using the arithmetic average and standard deviation from the value of the synthetic level indicator of a Knowledge-Based Economy. The following typology of voivodeships was obtained:

- I class (high level),
- II class (higher medium level),
- III class (lower medium level),
- IV class (low level).

## Results

The starting point for the research were independent variables – simple features, proposed by KAM. Most of the variables having an impact on the ranking of Polish voivodeships in terms of KBE in 2009-2016 concern the first three pillars: the economic and institutional incentive system, education and human resources as well as the innovation system. This means that Polish voivodeships do not differ significantly in terms of level of information technology development. Important variables describing the fourth pillar are simple features, unrelated to the “computerization” of the population, but related to industry.

In addition, most of the simple features analyzed are benefit criteria. This means that higher values of these indicators affect the higher position of the voivodeship in the ranking.

Final values of the synthetic indexes of a Knowledge-Based Economy for voivodeships of Poland in 2009-2016 obtained by the TOPSIS method and the rankings of voivodeships are presented in table 1.

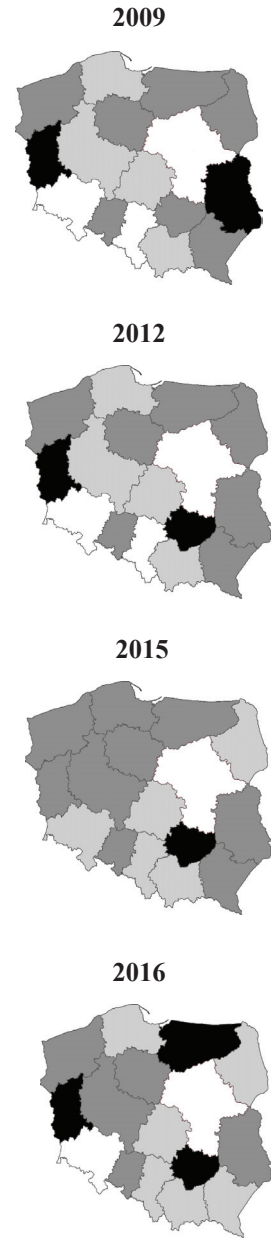
In most voivodeships, significant differences in position in particular years can be observed. Only Mazowieckie Voivodeship occupies a stable first position in all years and Dolnośląskie Voivodeship, which initially occupies third position, after the crisis in 2012, moves into second position.

Voivodeships characterized by the highest diversification in the ranking in terms of KBE advancement in 2009-2016 are as follows: Podlaskie (difference of 8 places), Świętokrzyskie (7 places), Lubelskie and Wielkopolskie (6 places). The remaining voivodeships are characterized by

Table 1. Final values of synthetic indexes of a Knowledge-Based Economy and rankings of Polish voivodeships in 2009-2016 within the KBE advancement level

Voivodeship	2009		2010		2011		2012		2013		2014		2015		2016	
	index	ranking	index	ranking	index	ranking	index	ranking	index	ranking	index	ranking	index	ranking	index	ranking
Dolnośląskie	0.53	3	0.60	3	0.55	2	0.57	3	0.55	2	0.61	2	0.56	2	0.60	2
Kujawsko-pomorskie	0.41	8	0.39	8	0.37	8	0.27	11	0.29	12	0.39	10	0.38	12	0.39	10
Lubelskie	0.28	15	0.35	13	0.27	13	0.28	10	0.35	10	0.38	11	0.33	14	0.39	9
Lubuskie	0.27	16	0.35	12	0.25	15	0.20	16	0.27	14	0.25	15	0.34	13	0.27	15
Łódzkie	0.46	7	0.46	7	0.42	7	0.44	5	0.45	5	0.45	6	0.51	4	0.50	4
Małopolskie	0.49	5	0.50	6	0.47	4	0.46	4	0.51	3	0.49	5	0.55	3	0.53	3
Mazowieckie	0.67	1	0.73	1	0.71	1	0.71	1	0.74	1	0.76	1	0.76	1	0.76	1
Opolskie	0.31	13	0.36	10	0.30	12	0.26	13	0.34	11	0.43	8	0.40	10	0.37	12
Podkarpackie	0.35	10	0.36	11	0.34	10	0.33	8	0.35	9	0.41	9	0.43	9	0.46	7
Podlaskie	0.31	12	0.39	9	0.34	9	0.28	9	0.39	8	0.34	13	0.49	5	0.44	8
Pomorskie	0.50	4	0.51	4	0.46	5	0.41	6	0.42	7	0.50	4	0.44	7	0.49	5
Śląskie	0.57	2	0.60	2	0.52	3	0.61	2	0.48	4	0.53	3	0.47	6	0.47	6
Świętokrzyskie	0.39	9	0.32	16	0.26	14	0.22	15	0.24	15	0.23	16	0.19	16	0.21	16
Warmińsko-mazurskie	0.33	11	0.33	15	0.25	16	0.22	14	0.24	16	0.29	14	0.31	15	0.29	14
Wielkopolskie	0.47	6	0.51	5	0.42	6	0.39	7	0.43	6	0.45	7	0.43	8	0.37	11
Zachodniopomorskie	0.30	14	0.34	14	0.34	11	0.26	12	0.29	13	0.36	12	0.38	11	0.34	13

Source: own elaboration based on [OECD 1996]

Figure 1. Voivodeships of Poland divided into classes, according to the synthetic index of the KBE advancement level, calculated by the TOPSIS method in the years 2009, 2012, 2015, 2016  
Source: own elaboration

an average diversity in the ranking – from 3 to 5. It is worth noting that Śląskie Voivodeship, which held a stable position at the forefront of the rate in 2009-2012, recorded a drop in the ranking in 2012-2016. Warmińsko-Mazurskie, Świętokrzyskie and Lubuskie Voivodeships close the ranking over the analyzed period. It is evident that the Operational Programme Eastern Poland 2007-2013, co-financed from EU funds, effectively impacted the promotion in the ranking of these voivodeships.

Below is the typology of voivodeships within KBE in 2009 – the beginning of the crisis, 2012 – exit from crisis, 2015 – financial end of the perspective 2007-2013 and 2016 – the last year in which complete data is available using maps in figure 1. The shades of grey show the affiliation of voivodeships to one of four typological classes.

The first class includes voivodeships with a high level of Knowledge Based Economy advancement. In 2009 (the beginning of the crisis) and 2012 (the exit from the crisis), the following voivodeships belonged to this class: Śląskie, Dolnośląskie and Mazowieckie, in 2015 – only Mazowieckie, but in 2016 – Mazowieckie and Dolnośląskie. Voivodeships characterized by the lowest level of information technology development were qualified to the fourth class and are: Lubelskie and Lubuskie in 2009, Świętokrzyskie and Lubuskie in 2012, in 2015 – only Świętokrzyskie, in 2016 – Lubuskie, Warmińsko-Mazurskie and Świętokrzyskie. It can therefore be concluded that the crisis failed to significantly deepen the disproportion between the KBE development level in voivodeships (compare maps for 2009 and 2012 in fig. 1).

European Funds 2007-2013, the use of which ended in 2015, strongly influenced the alignment Knowledge Based Economy level of Polish voivodeships. As many as 14, out of 16 belonged to two middle classes of KBE advancement in 2015 (fig. 1 – 2015 in comparison with 2009 and 2012). However, the unification did not cover voivodeships with the highest and lowest level of KBE development (the first and fourth classes), which significantly differ from the two middle classes which are relatively even (fig. 1 – 2015).

A differentiation in KBE level took place once again in 2016. The probable reason is the end of EU programmes for the years 2007-2013 and a lack of visible effects of new, launched funds from the 2014-2020 programmes.

In addition, no differences were found between voivodeships located in the West and East part of Poland over the considered period.

### **Conclusions and further research directions**

The obtained results constitute an analysis of a Knowledge-Based Economy. The conducted research showed disproportions between voivodeships in terms of KBE development level, and also confirmed that programmes aimed at aligning the level between the voivodeships bring tangible results.

The analysis can form a basis for assessing the use of knowledge in the process of voivodeship economic development. The presented research results, should form the initial stage for foresight research, concerning the prediction of future KBE development, which may, in turn, help to create regional innovation strategies and facilitate their monitoring.

It should be noted, however, that there is no one recognized method for measuring the level of a Knowledge-Based Economy and the conducted research can only be used as one among other proposals in subject literature.

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### Streszczenie

Celem artykułu jest próba pomiaru poziomu rozwoju gospodarki opartej na wiedzy (KBE). Zastosowana metodyka KAM (Knowledge Assessment Methodology), opracowana przez Bank Światowy w 1999 roku, jest jedną z metod pomiaru stopnia rozwoju KBE. Polega ona na opracowaniu zestawu wskaźników opisujących funkcjonowanie poszczególnych wymiarów społeczno-gospodarczych, pogrupowanych w cztery kategorie: (A) gospodarcze i instytucjonalne, (B) edukacja i zasoby ludzkie, (C) system informacji i nowe technologie, (D) technologie informacyjne. Analiza tych filarów pomaga uzyskać przewagę konkurencyjną (region, przemysł, gospodarka narodowa). Obliczono wskaźniki syntetyczne dla województw Polski w latach 2009-2016. Wyniki badań wykazują znaczną różnicę przestrzenną w rozwoju KBE. Zmiany w tej dywersyfikacji województw przedstawiono dla lat 2015 i 2016 w odniesieniu do lat 2012 i 2009.

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