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KNOWLEDGE-BASED ECONOMY IN THE EUROPEAN UNION – CROSS-COUNTRY ANALYSIS

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ABSTRACT

The knowledge-based economy is an economy where knowledge is created, acquired, transmitted and used effectively by businesses, organizations, individuals and communities. It is not narrowly focused on the industries of advanced technology or ICT, but provides a framework for analysing the range of policy options in education, information infrastructure and systems of innovation, which could help contribute to the knowledge economy. The aim of the paper is to analyse spatial differences in the level of development of the knowledge-based economy in the European Union countries. The study uses a soft modelling method, which enables the estimation of a synthetic measure of KBE as well as the arrangement and classification of the UE-27 countries into typological groups. The research covers the years 2000 and 2013.

Key words: knowledge-based economy, knowledge assessment methodology, economic development, soft modelling.

1. Introduction

On the one hand, the knowledge-based economy (KBE) is perceived in a narrow sense as a part of economy dealing with knowledge industry, mainly science. However, in a broader sense, it is understood as the economy whose one production factor is knowledge (Piech, 2009, pp. 214). The classical definition of KBE is the one proposed by Organization for Economic Co-operation and Development(OECD), which defines it as an economy directly depending on knowledge and information production, distribution and use (OECD, 1996, pp. 7). The Asia-Pacific Economic Co-operation Economic Committee defined KBE as an economy in which the production, distribution, and the use of knowledge is the main driver of growth, wealth creation and employment across all industries (APEC Economic Committee, 2000, p. vii). According to the definition coined by the OECD and the World Bank Institute, KBE is an economy where knowledge is created, acquired, transmitted and used effectively by enterprises, organizations,

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individuals and communities. It does not focus narrowly on high-technology industries or on information and communications technologies, but rather provides a framework for analysing a range of policy options in education, information infrastructure and innovation systems that can help usher in the knowledge economy (OECD, World Bank, 2001, pp. 3).

The vital work on KBE was the OECD report published in 1996, in which the notion of the 'knowledge economy' was used for the first time. Although during the last 20 years multiple studies have been conducted and numerous works have been written on KBE, one widely accepted measurement method has not been arrived at. We can only list a few dominant measurement methods, such as the Knowledge Assessment Methodology (KAM), drawn up by the World Bank, or the methodology proposed by the OECD. The work on them is still in progress, and each methodology is subject to constant criticism (Piech, 2009, pp. 315).

The paper focuses on the issue of measuring KBE in the European Union countries. KBE is difficult to measure due to its complexity, multidimensionality and unobservability. Its measurement requires prior solution to various problems such as: the imprecise and unquantifiable definition of KBE, the choice of the method, the choice of indicators referring to different aspects of KBE, the choice of an optimal set of indicators, data availability.

The aim of the paper is to analyse spatial differences in the KBE development level in the European Union countries (UE-27) in two periods of time – the years 2000 and 2013.In this study the concept of KBE measurement is based on KAM methodology and the soft modelling method. The following research hypotheses have been formulated:

H1: Observable variables (indicators) do not play equally important roles in reflecting the KBE development level in the European Union countries.

H2: Positive correlations between the pillars of KBE and the KBE development level in the European Union countries exist.

H3: A positive correlation between the KBE development level and the economic development level in the European Union countries exist.

2. Research method

In the literature the description of the soft modelling method can be found in (Wold, 1980), its generalization in (Rogowski, 1990) and examples of application in (Perło, 2004), (Skrodzka, 2015).

A soft model enables conducting the research of unobserved variables (latent variables). The values of these variables cannot be directly measured due to the lack of a generally accepted definition or the absence of a clear way of measuring them. A soft model consists of two sub-models:

- an internal sub-model – a system of relationships among latent variables, which describes the relationship arising from the theory,

- an external sub-model – defines the latent variables based on observed variables, known as indicators.

The indicators enable indirect observation of latent variables and are selected following the chosen theory or the researcher's intuition. In soft modelling, a latent variable can be defined by indicators in two ways: inductively – this approach is based on the assumption that indicators create latent variables (formative indicators) or deductively – this approach is based on the assumption that indicators reflect their theoretical notions (reflective indicators). In both approaches, latent variables are estimated as weighted sums of their indicators.

A soft model is constructed similarly to classical econometric models, with the following stages:

-specification of an internal sub-model (describing relationships among latent variables),

- specification of an external sub-model (describing latent variables by indicators),
- estimating model parameters with the Partial Least Square (PLS method), and
- statistical verification of a model (Stone-Geisser test and “2s” rule).

The Stone-Geisser test measures the prognostic property of a soft model. Its values are in the range from $-\infty$ to 1. A positive (negative) value of this test indicates high (poor) quality of the model.“2s” rule says that if the doubled standard deviation, calculated based on the Tukey cut method, is lower than the absolute value of the parameter estimator, the parameter is statistically significant.

As a result of using the PLS method, we obtain estimates of latent variables, which can be regarded as synthetic measures. These quantities depend not only on external relations but also on relations among latent variables assumed in the internal model. It means that the cognition depends not only on the definition of a given notion but also on the theoretical description. Soft modelling makes full use of theoretical and empirical knowledge. This is one of the things which distinguishes the presented method from most of the commonly applied methods of multidimensional comparative analysis (this is also characteristic of structural models),

In this study the concept of KBE measurement is also based on the KAM methodology, which was developed within the framework of “The Knowledge for Development” (K4D) programme. The KAM methodology is regarded as the most efficient way of measuring KBE. It specifies four key pillars:

- Economic Incentive and Institutional Regime, responsible for developing economic policy and the work of institutions. The extension, dissemination and the use of knowledge by these entities is supposed to ensure effectiveness by an adequate division of resources and by boosting creativity.
- Education and Human Resources, which means personnel who can adapt to constantly developing technological solutions thanks to upgrading their skills.

- Innovation System, which involves the activities of economic entities, research centres, universities, advisory bodies and other organizations whose operations are adjusted to preferences of more and more demanding customers.
- Information Infrastructure, which ensures effective communication and faster transfer of data. All these aspects influence the transfer of information and knowledge (Chen, Dahlman, 2005, pp. 5–9).

The pillars are used to construct two global indexes:

- Knowledge Index (KI), which determines the knowledge potential of a country; this indicator is calculated as an arithmetic average of the three subindexes, which represent the three pillars of KAM (except the Economic Incentive and Institutional Regime);
- Knowledge Economy Index (KEI), which determines a general development level of the knowledge-based economy; this indicator is calculated as an arithmetic average of the four subindexes, which represent the four pillars of KAM (Chen, Dahlman, 2005, pp. 9–13).

The advantages of this method are: simplicity, clarity and versatility. It enables the comparison of the KI and KEI indicators and their components in both dimensions: intertemporal and international. The method is criticised, inter alia, for: insufficient theoretical background, the tendency to repeat information by indicators, the lack of differentiated weights for indicators, insufficient information about many of the analysed economies, inaccessibility of indicators in the systems of international statistics, incomparability of data due to a variety of data sources (Becla, 2010, pp. 56–70).

3. Specification of soft model

Figure 1 presents the concept of the internal sub-model. The concept assumes the relationship between two unobserved variables: the level of development of KBE and the level of economic development. KBE is defined by four pillars (according to KAM methodology): economic regime, education and human resources, innovation system and information infrastructure. They are also unobserved. Hence, KBE is the second-order latent variable.

The estimated model consists of two following equations:

$$KBE = \alpha_1 REG + \alpha_2 EDU + \alpha_3 INN + \alpha_4 ICT + \alpha_0 + \varepsilon \qquad (1)$$

$$ED = \beta_1 KBE + \beta_0 + \xi \qquad (2)$$

where

KBE –level of development of knowledge-based economy,

REG – economic regime,

EDU – education and human recourses,

INN – innovation system,

ICT – information infrastructure,

ED –level of economic development,

α_0, α_1,α_2,α_3,α_4, β_0, β_1 – structural parameters,

ε, ξ– error terms.

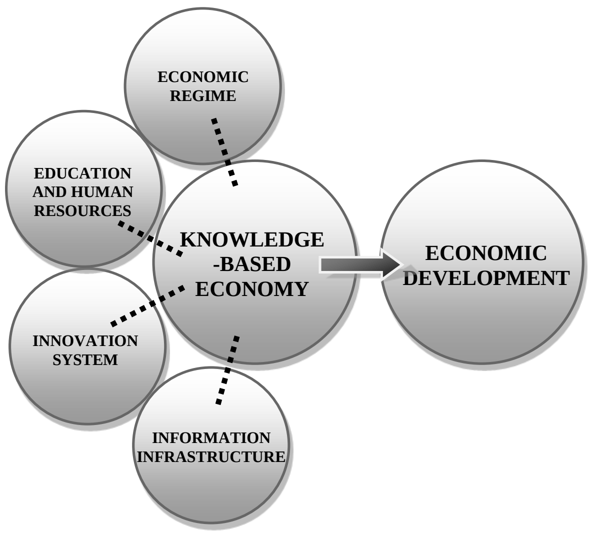

Figure 1. The concept of the internal sub-model

Source: own elaboration.

Each of the latent variables is defined by a set of indicators (see Table 1) based on a deductive approach. Data used to specify the model are taken from Eurostat and refer to 27 countries. Croatia was excluded from the research because of the large amount of missing data. The research focuses on the years 2000 and 2013,which is also related to the availability of data.

The following items were measured statistically: the variability of indicators (the coefficient of variation above 10%), the correlation level (depending on the way a latent variable is defined by indicators, an inductive or a deductive approach, indicators should show low or high correlation respectively). Missing data were complemented using native forecasting – complemented by adjacent values.

Table 1. Indicators of latent variables

Latent variable		Indicator	Meaning	Type of indicator
KBE	*REG*	*REG01*	Direct investment flows (% of GDP)	stimulant
		REG02	Exports of goods and services (% of GDP)	stimulant
		REG03	Business enterprise R&D expenditure (% of GDP)	stimulant
	EDU	*EDU04*	Persons with tertiary education attainment (%)	stimulant
		EDU05	Employees with tertiary education attainment (%)	stimulant
		EDU06	Life-long learning of persons aged 25-64 (%)	stimulant
		EDU07	Graduates (ISCED 5-6) in mathematics, science and technology (% of all fields)	stimulant
	INN	*INN08*	Persons employed in science and technology (% of total population)	stimulant
		INN09	Researchers in business enterprise sector (per 10 000 employees)	stimulant
		INN10	Total intramural R&D expenditure (% of GDP)	stimulant
	ICT	*ICT11*	Individuals who used computer in last 3 months (% of total population)	stimulant
		ICT12	Households with Internet access (%)	stimulant
		ICT13	Persons employed using computers with access to World Wide Web (% of total employment)	stimulant
ED		*ED01*	Gross domestic product per capita (PPS)	stimulant
		ED02	Gross value added per employee (PPS)	stimulant
		ED03	The share of agriculture in gross value added (%)	destimulant
		ED04	The share of professional, scientific and technical activities in gross value added (%)	stimulant
		ED05	Gini coefficient	destimulant

Source: own elaboration.

4. Diversity of knowledge-based economy in the European Union countries in 2000 – results of soft model estimation

The model presented in Figure 1 was estimated using the PLS software (created by J. Rogowski) based on data which refer to 2000. Table 2 contains estimates of the parameters of the external sub-model(weights, loadings) and standard deviations calculated based on the Tukey cut method. Indicators are ordered in decreasing order with regard to the absolute values of loadings (if the deductive approach is used to define the latent variable, we should interpret loadings).

Table 2. Estimates of the parameters of the external sub-model MM2000

Latent variable	Indicator	Weight	Standard deviation	Loading	Standard deviation
REG	*REG03*	0.8567	0.0118	0.9118	0.0091
	REG01	0.2547	0.0119	0.5340	0.0174
	REG02	0.1977	0.0112	0.4188	0.0185
EDU	*EDU04*	0.3647	0.0008	0.8940	0.0010
	EDU05	0.2806	0.0013	0.7967	0.0014
	EDU06	0.4829	0.0014	0.7566	0.0010
	EDU07	0.1984	0.0025	0.4282	0.0023
INN	*INN10*	0.3608	0.0012	0.9592	0.0001
	INN09	0.3510	0.0014	0.9278	0.0002
	INN08	0.3602	0.0003	0.9114	0.0001
ICT	*ICT11*	0.3633	0.0001	0.9608	0.0000
	ICT13	0.3486	0.0006	0.9528	0.0001
	ICT12	0.3351	0.0006	0.9511	0.0001
KBE	*ICT11*	0.1346	0.0010	0.9543	0.0005
	REG03	0.1289	0.0012	0.9177	0.0010
	ICT13	0.1285	0.0026	0.9157	0.0022
	INN10	0.1237	0.0014	0.9024	0.0032
	INN08	0.1251	0.0006	0.9009	0.0004
	ICT12	0.1342	0.0012	0.8802	0.0013
	INN09	0.1225	0.0034	0.8778	0.0035
	EDU06	0.0993	0.0033	0.7937	0.0060
	EDU04	0.0689	0.0025	0.5994	0.0064
	EDU05	0.0489	0.0027	0.4612	0.0060
	EDU07	0.0542	0.0012	0.3261	0.0015
	REG01	0.0568	0.0102	0.2728	0.0162
	REG02	0.0457	0.0069	0.2118	0.0146
ED	*ED01*	0.3176	0.0408	0.9393	0.1415
	ED02	0.2708	0.0383	0.9173	0.0998
	ED03	-0.2812	0.0271	-0.8437	0.0523
	ED04	0.2047	0.0460	0.7108	0.1292
	ED05	-0.1853	0.0414	-0.3810	0.0913

Source: own calculation.

All parameters are statistically significant (“2s” rule). Moreover, the results are consistent with expectations. The stimulants have positive weights and loadings and destimulants have negative ones.

Indicators have a different strength of impact on latent variables. *REG* variable is very strongly correlated with*REG03* indicator and moderately correlated with *REG01* and *REG02* indicators. *EDU* variable is strongly reflected by *EDU04*, *EDU05*, *EDU06* indicators and moderately reflected by*EDU07* indicator.*INN* and *ICT* variables are very strongly correlated with all indicators that define them. *KBE* variable is very strongly reflected by *ICT11, REG03, ICT13, INN10, INN08* indicators, while indicators *REG01*, *REG02* are weakly correlated with this variable. *ED* variable is very strongly correlated with *ED01* and *ED02* indicators, strongly correlated with *ED03* and *ED04* indicators, and weakly correlated with *ED05* indicator.

Equations (3) and (4) present estimations of the parameters of the internal sub-model. Standard deviations calculated based on the Tukey cut method are given in brackets.

$$\hat{KBE} = \underset{(0.0286)}{0.2213}REG + \underset{(0.0050)}{0.1967}EDU + \underset{(0.0196)}{0.2844}INN + \underset{(0.0055)}{0.3869}ICT + \underset{(0.0156)}{0.0553} \quad (3)$$

$$\hat{ED} = \underset{(0.0439)}{0{,}7612}KBE - \underset{(0.3840)}{1{,}7854} \quad (4)$$

The signs of estimators are consistent with expectations. Furthermore, all latent variables are statistically significant (“2s” rule). The coefficient of determination (R^2) has the value of 1.0 for the equation (3) and the value of 0.6 for the equation (4). The general Stone-Geisser test is equal to 0.31. The model can be verified positively.

All four pillars have a positive influence on the level of KBE development (see equation 3). The pillar “information infrastructure” has the strongest impact (0.3869) and “education and human recourses” has the lowest (0.1967). The equation (4) shows that the relationship between the level of KBE development and the level of economic development is positive and strong (compare with (Dworak, 2010)).

Estimates of the values of latent variables were used to order the UE-27 countries according to the level of KBE development and to classify countries into four typological groups. Groups were constructed based on the parameters of a synthetic measure: average and standard deviation (Nowak, 1990, pp. 92–93):

- I group – very high level of KBE development,
- II group – high level of KBE development,
- III group – medium and low level of KBE development,
- IV group – very low level of KBE development.

Figure 2 presents the results of the classification.

1.	Sweden	15.	Cyprus
2.	Finland	16.	Czech Republic
3.	Denmark	17.	Malta
4.	Luxembourg	18.	Slovakia
5.	United Kingdom	19.	Lithuania
6.	Netherlands	20.	Italy
7.	Germany	21.	Latvia
8.	Belgium	22.	Hungary
9.	Austria	23.	Poland
10.	France	24.	Greece
11.	Ireland	25.	Portugal
12.	Slovenia	26.	Bulgaria
13.	Estonia	27.	Romania
14.	Spain		

Figure 2. The level of development of the knowledge-based economy in the UE-27 countries in 2000

Source: own elaboration.

A very high level of KBE development was achieved in 2000 by: Sweden, Finland, Denmark, Luxemburg and United Kingdom. Six countries: Netherlands, Germany, Belgium, Austria, France and Ireland a had high level of KBE development. The group of countries with a medium and a low level of KBE development included Slovenia, Estonia, Spain, Cyprus, Czech Republic, Malta, Slovakia, Lithuania, Italy, Latvia, Hungary and Poland. Greece, Portugal, Bulgaria and Romania were in the last group with very low level of KBE development. Poland was 23rd in the ranking and was classified in the third group.

5. Diversity of knowledge-based economy in the European Union countries in 2013 – results of soft model estimation

Table 3 contains estimates of the parameters of the external sub-model and standard deviations. All parameters are statistically significant. Furthermore, the results are consistent with expectations – stimulants have positive weights and loadings and destimulants have negative ones.

Table 3. Estimates of the parameters of the external sub-model

Latent variable	Indicator	Loading	Standard deviation	Weight	Standard deviation
REG	REG03	0.9480	0.0123	0.8817	0.0175
	REG01	0.3190	0.0119	0.3511	0.0347
	REG02	0.1883	0.0192	0.2767	0.0353
EDU	EDU04	0.3573	0.0013	0.8957	0.0016
	EDU05	0.2803	0.0021	0.8085	0.0022
	EDU06	0.4945	0.0038	0.7704	0.0026
	EDU07	0.1822	0.0010	0.3975	0.0010
INN	INN09	0.3644	0.0009	0.9646	0.0004
	INN10	0.3360	0.0022	0.9289	0.0008
	INN08	0.3824	0.0033	0.8795	0.0012
ICT	ICT11	0.3465	0.0004	0.9738	0.0001
	ICT12	0.3413	0.0008	0.9686	0.0001
	ICT13	0.3515	0.0013	0.9447	0.0002
KBE	ICT13	0.1302	0.0018	0.9484	0.0027
	ICT11	0.1336	0.0009	0.9349	0.0019
	INN08	0.1350	0.0028	0.9243	0.0044
	ICT12	0.1385	0.0012	0.9209	0.0028
	INN09	0.1197	0.0017	0.8809	0.0055
	EDU06	0.1110	0.0022	0.8614	0.0047
	INN10	0.1088	0.0026	0.8123	0.0083
	REG03	0.1095	0.0024	0.7978	0.0077
	EDU04	0.0835	0.0012	0.6223	0.0036
	EDU05	0.0656	0.0015	0.4883	0.0047
	EDU07	0.0510	0.0023	0.3174	0.0024
	REG01	0.0592	0.0087	0.2685	0.0168
	REG02	0.0413	0.0075	0.1584	0.0166
ED	ED01	0.2673	0.0316	0.8982	0.1093
	ED03	-0.2742	0.0342	-0.8860	0.0734
	ED02	0.2192	0.0578	0.8497	0.0870
	ED04	0.2247	0.0505	0.8121	0.0788
	ED05	-0.2332	0.0404	-0.6356	0.1540

Source: own calculation.

REG variable is strongly correlated with *REG03* indicator and weakly correlated with *REG01* and *REG02* indicators. *EDU* variable is strongly reflected by *EDU04*, *EDU05*, *EDU06* indicators and weakly reflected by *EDU07* indicator. *INN* and *ICT* variables are very strongly correlated with all indicators that define them. *KBE* variable is very strongly reflected by *ICT13*, *ICT11*,*INN08*, *ICT12* indicators, while indicators:*EDU07*, *REG01*, *REG02* are weakly correlated with this variable. *ED* variable is strongly correlated with all indicators except for one – ED05.

Equations (5) and (6) present estimations of the parameters of the internal sub-model.

$$\hat{KBE} = \underset{(0.0219)}{0.1945}REG + \underset{(0.0034)}{0.2374}EDU + \underset{(0.0322)}{0.2221}INN + \underset{(0.0104)}{0.4312}ICT + \underset{(0.0157)}{0.0523} \quad (5)$$

$$\hat{ED} = \underset{(0.0402)}{0.8053}KBE - \underset{(0.8033)}{3.8929} \quad (6)$$

The signs of estimators are consistent with expectations. Moreover, all latent variables are statistically significant (“2s” rule). The coefficient of determination (R^2) has the value of 1.0 for the equation (5) and the value of 0.65 for the equation (6). The general Stone-Geisser test is equal to 0.27. The model can be verified positively.

All four pillars have a positive influence on the level of KBE development. The pillar “information infrastructure” has the strongest impact (0.4312) and “economic regime” has the lowest (0.1945). The equation (6) shows that the relationship between the level of KBE development and the level of economic development is positive and strong.

Figure 3 presents the results of classification of the UE-27 countries according to the level of KBE development in 2013. Countries are divided into four groups. The first group– countries with the highest level of KBE development – consists of: Sweden, Finland, Denmark, Finland and Luxemburg. Countries: Netherlands, United Kingdom, Germany, France, Ireland, Belgium, Austria, Slovenia and Estonia are in the second group and have a high level of KBE development. The third group includes: Czech Republic, Spain, Malta, Hungary, Lithuania, Cyprus, Latvia, Slovakia, Poland, Portugal and Italy. They have medium and low level of KBE development. Very low level of KBE development is characteristic for: Greece, Bulgaria and Romania. Poland was 22nd in the ranking and was classified in the third group.

1.	Sweden	**15.**	Spain
2.	Denmark	**16.**	Malta
3.	Finland	**17.**	Hungary
4.	Luxembourg	**18.**	Lithuania
5.	Netherlands	**19.**	Cyprus
6.	United Kingdom	**20.**	Latvia
7.	Germany	**21.**	Slovakia
8.	France	**22.**	Poland
9.	Ireland	**23.**	Portugal
10.	Belgium	**24.**	Italy
11.	Austria	**25.**	Greece
12.	Slovenia	**26.**	Bulgaria
13.	Estonia	**27.**	Romania
14.	Czech Republic		

Figure 3. The level of development of the knowledge-based economy in the UE-27 countries in 2013

Source: own elaboration.

6. Conclusions

The studies presented in the paper concerned the analysis of spatial differences in the KBE development level in the EU-27 countries. The soft modelling method used in research enabled:

- the investigation into the relationships between indicators and the KBE latent variable,
- the investigation into the relationships between the pillars of KBE and the KBE development level as well as between the KBE development level and the economic development level in the European Union countries,
- the estimation of the values of KBE synthetic measure and the arrangement of countries according to the KBE development level as well as the division of counties into typological groups.

In both estimated models (2000 and 2013) indicators had a different strength of impact on the KBE latent variable (from very strong to weak). Moreover, both estimated models indicated positive influence of the KBE pillars on the KBE development level. Furthermore, in both estimated models the relationship between the KBE development level and the economic development level was positive and strong. Hence, the hypotheses which were formulated in the introduction can be positively verified.

The highest level of development of the knowledge-based economy both in 2000 and in 2013 was characteristic for Sweden, Denmark, Finland and Luxembourg, whereas the lowest one for Greece, Bulgaria and Romania. Four of the 27 countries were classified into other typological groups in 2013 compared to 2000. The United Kingdom was classified into the group with a lower level of KBE development, while Slovenia, Estonia and Portugal to the group with a higher level of KBE development. Eleven countries, including Poland, improved their ranking in 2013 compared to 2000, while nine countries reduced their positions. The highest increase was in Hungary (22nd position in 2000 and 17th position in 2013) and the largest fall in Italy (22nd position in 2000 and 24th position in 2013).

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