DEVELOPMENT OF KNOWLEDGE-BASED ECONOMY
IN EUROPEAN UNION IN 2000-2014

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Abstract: Knowledge-based economy (KBE) is an economy where knowledge is created, acquired, transmitted and used effectively by businesses, organizations, individuals and communities. The concept of KBE was emphasised in the EU programmes such as the Lisbon Strategy and the Europe 2020 Strategy. One of the three priorities of the Europe 2020 Strategy is to promote smart growth, understood as developing an economy based on knowledge and innovation. The aim of the paper is to analyze the development of KBE in European Union in period 2000-2014. The concept of KBE measurement is based on Knowledge Assessment Methodology and the soft modeling method.

Keywords: knowledge-based economy, economic development, soft modeling, KAM methodology

INTRODUCTION

Recent years have witnessed numerous changes in economic theories, especially with reference to the following concepts:
- information society, i.e. the one which uses teleinformation technologies intensively,
- knowledge-based economy (KBE), including "the new economy" (teleinformation technologies it promotes), issues in education (knowledge society), as well as innovation systems, and the institutional system, which is considered indispensable for the development of the above-mentioned elements [Piech 2009, pp. x-xi].
These concepts were emphasised in the European Union (EU) programmes such as the Lisbon Strategy and the Europe 2020 Strategy. The Lisbon Strategy stated that "knowledge and innovation will be the beating heart of the European

growth" [European Commission 2005, pp. 4]. The Europe 2020 Strategy, a new long-term European growth programme, which replaced the Lisbon Strategy, stresses the need for a greater coordination of the EU member states in order to overcome the crisis and implement the reforms which will enable us to face the challenges of globalization, ageing societies and a growing need for resource efficiency. Therefore, three priorities were determined:
- smart growth – developing an economy based on knowledge and innovation,
- sustainable growth – promoting a more resource efficient, greener and more competitive economy,
- inclusive growth – fostering a high-employment economy delivering economic, social and territorial cohesion [European Commission 2010, p. 8].

The paper focuses on the issue of measuring of knowledge-based economy in European Union. KBE is difficult to measure due to its complexity, multidimensionality, unobservability. Its measurement requires prior solution of various problems such as: the imprecise and unquantifiable definition of KBE, the choice of 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 analyze the development of KBE in European Union in period 2000-2014. The concept of KBE measurement is based on Knowledge Assessment Methodology (KAM) and the soft modeling method.

DEFINING AND MEASURING KNOWLEDGE-BASED ECONOMY

Knowledge-based economy is on one hand 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, p. 214]. The classical definition of KBE is the one proposed by Organisation 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, p. 7]. The Asia-Pacific Economic Co-operation (APEC) Economic Committee defined KBE as an economy in which the production, distribution, and 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, individuals and communities. It does not focus narrowly on high-technology industries or on information and communications technologies, but rather presents a framework for analyzing a range of policy options in education, information infrastructure and innovation systems that can help usher in the knowledge economy [OECD, World Bank 2001, p. 3]. It is also assumed that KBE consists of four pillars:
- human capital, in whom some knowledge is stored,

- innovation system with entrepreneurship, more focused on businesses but also on cooperation with science, which also creates new knowledge,
- teleinformation technologies, which facilitate knowledge exchange, also abroad,
- institutional and legal environment, which creates conditions for the development of the above-mentioned areas [Piech 2009, p. 217].

KBE was first measured by F. Machlup, who regrouped economic branches and created a brand new sector – knowledge. The vital work on KBE was the OECD report published in 1996, where the notion of the "knowledge economy" was used for the first time. In 1998, the World Bank created Knowledge Assessment Methodology (KAM). In the same year, the Progressive Policy Institute presented the index of the new economy. A year later, the APEC initiated a project called: "Towards Knowledge-based Economies in APEC". At the beginning of the year 2000, the Australian Statistical Office started research into the knowledge-based economy and society ("Measuring a Knowledge-based Economy and Society"). In the same year, the Harvard University Center for International Development published a report: "Readiness for the Networked World". It presented the ranking list of countries based on the criterion of the readiness. In 2002, the UNECE published its own knowledge-based economy model "Regional Assessment Report" [Dworak 2014, pp. 11-12].

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 achieved. We can only list a few dominant measurement methods, such as the KAM, drawn up by the World Bank, or the methodology proposed by the OECD. The methodologies have constantly been developed and each of them is a subject to constant criticism [Piech 2009, p. 315].

The KAM, which was developed within the framework of "The Knowledge for Development" (K4D) programme, is regarded as the most developed way of measuring KBE. It distinguishes four key pillars:
- Economic Incentive and Institutional Regime; indicators: tariff and non-tariff barriers, regulatory quality, rule of law.
- Education and Human Resources; indicators: adult literacy rate (% age 15 and above), latest version – average years of schooling, secondary enrollment, tertiary enrollment.
- Innovation System; indicators: researchers in R&D, per million population or in the latest version: payments and income from licence fees, patents applications granted by the US Patent and Trademark Office, per million population, scientific and technical journals articles, per million population.
- Information Infrastructure; indicators: telephones per 1000 persons (telephone mainlines and mobile phones), computers per 1000 persons, Internet users per 10000 persons.

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 three subindexes, which

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

The advantages of this method are its simplicity, clarity and versatility. It enables 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].

In this study the concept of KBE measurement is based on KAM methodology and the soft modeling method. In the literature description of the soft modeling method can be found in [Wold 1980], its generalization in [Rogowski 1990] and examples of application in [Perło 2004, Skrodzka 2015].

THE CONCEPT OF SOFT MODEL

Soft model[1] enables to research unobserved variables (latent variables). The values of these variables cannot be directly measured because the lack of a generally accepted definition or the absence of a clear way of measuring them. Soft model consists of two sub-models: the internal sub-model – a system of relationships among latent variables, which describes the relationship arising from the theory and the external sub-model – defines the latent variables based on observed variables, known as indicators.

Indicators enable indirect observation of latent variables and are selected following a chosen theory or the researcher's intuition. In soft modeling, 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 [Rogowski 1990, pp. 25-26].

A soft model is constructed similarly to classical econometric models, with the following stages:
Stage I: describing relationships among latent variables in an internal model (specification of an internal model).

[1] Soft modeling method was created by H. Wold [1980].

Stage II: describing latent variables by indicators (specification of an external model).

Stage III: estimating model parameters (the internal one and the external one simultaneously) with the Partial Least Square – PLS method.

Stage IV: content-based and statistical verification of a model (Stone-Geisser test and "2s" rule[2]).

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 cognition depends not only on the definition of a given notion but also on the theoretical description. Soft modeling makes full use of the theoretical and empirical knowledge. This is what among other things distinguishes the presented method from most of commonly applied methods of multidimensional comparative analysis[3].

Figure 1. The concept of internal sub-model
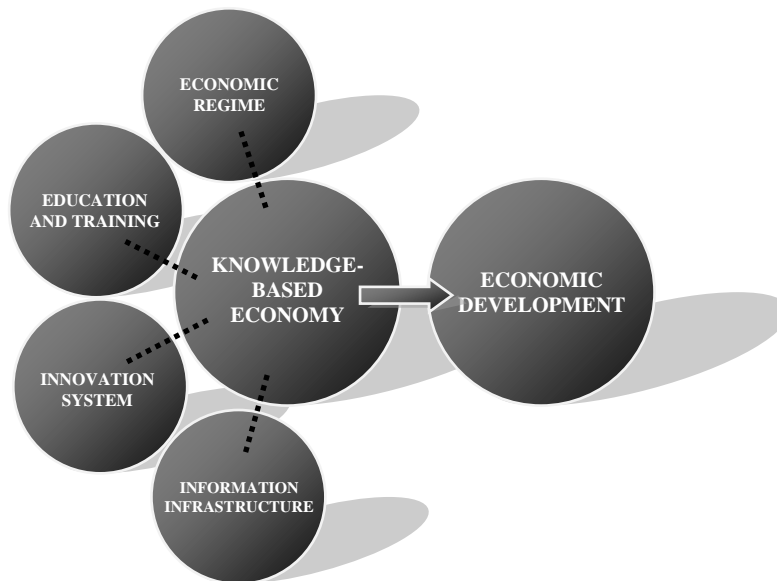
Source: own elaboration

Figure 1 presents the concept of internal sub-model. The concept assumes relationships between two unobserved categories: the level of development of knowledge-based economy and the level of economic development. KBE is defined by four pillars (according to KAM methodology): economic regime,

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[2] Parameter is statistically significant when value of double error is higher than value of estimator.

[3] This is also characteristic of structural models.

education and training, innovation system and information infrastructure. They are also unobserved. Hence KBE is the second-order latent variable.

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 − the level of development of knowledge-based economy,
REG − economic regime,
EDU − education and training,
INN − innovation system,
ICT − information infrastructure,
ED − the level of economic development,
α_0, α_1, α_2, α_3, $\alpha_{4,}$ β_0, β_1 − structural parameters,
ε, ξ − error terms.

Table 1. Indicators of latent variables

Latent variable		Indicator	Meaning	Type of indicator
KBE	REG	REG01	Gross capital formation (% of GDP).	stimulant
		REG02	Exports of goods and services (% of GDP).	stimulant
		REG03	Imports of goods and services (% 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 (per 1 000 inhabitants aged 20-29).	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	Households with Internet access (%).	stimulant
		ICT12	Persons employed using computers with access to World Wide Web (% of total employment).	stimulant
ED		ED01	Gross domestic product per capita (euro, chain linked volumes - 2010).	stimulant
		ED02	Gross value added per employee (euro, chain linked volumes - 2010).	stimulant
		ED03	Total investment (% of GDP).	stimulant
		ED04	The share of agriculture in gross value added (%).	destimulant
		ED05	The share of industry in gross value added (%).	stimulant

Source: own elaboration

Each of latent variables is defined by a set of indicators based on deductive approach (see Table 1). Data use to specify the model are taken from Eurostat[4] and they refer to period 2000-2014. Indicators of KBE pillars were selected based on the KAM methodology but a key element was data availability. The following items were measured statistically: the variability of indicators (the coefficient of variation above 5%), a correlation level[5]. Missing data were complemented by extrapolation of time series (19 observation from 255 – 7%).

ESTIMATION RESULTS

Model presented on Figure 1 was estimated using the PLS software[6]. Table 2 contains estimates of weights and loadings with regard to external sub-model. All parameters are statistically significant ("2s" rule).

Some results are not consistent with expectations. Indicator REG01 is a stimulant of both REG and KBE latent variables but it has negative weight and loading. The values of this indicator decreased in periods 2000-2003, 2007-2009 and 2011-2014. The average annual rate of decline was 1%. Indicators ED03 and ED04 are stimulant of ED variable but they have negative weights and loadings. It is due to a decrease in the value of these indicators in period 2000-2014 (average annual rates of decline were: 0.3% for ED03 and 2% for ED04).

Table 2. Estimates of weights and loadings of the external sub-model

Latent variable	Indicator	Loading	Standard deviation	Weight	Standard deviation
REG	REG01	-0.6555	0.0008	-0.3172	0.0006
	REG02	0.9755	0.0002	0.4274	0.0002
	REG03	0.9286	0.0003	0.4040	0.0003
EDU	EDU04	0.9870	0.0000	0.2713	0.0000
	EDU05	0.9915	0.0000	0.2714	0.0000
	EDU06	0.8840	0.0000	0.2216	0.0000
	EDU07	0.9894	0.0000	0.2701	0.0000
INN	INN08	0.9795	0.0001	0.3546	0.0000
	INN09	0.9865	0.0000	0.3563	0.0000
	INN10	0.9377	0.0001	0.3212	0.0000
ICT	ICT11	0.9990	0.0000	0.4996	0.0000
	ICT12	0.9990	0.0000	0.5014	0.0000

Source: own calculations

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[4] http://ec.europa.eu/eurostat/data/database

[5] 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.

[6] PLS software was created by J. Rogowski. It is available at Faculty of Economics and Management University of Bialystok.

Table 2. (continued) Estimates of weights and loadings of the external sub-model

Latent variable	Indicator	Loading	Standard deviation	Weight	Standard deviation
KBE	REG01	-0.6928	0.0015	-0.0665	0.0014
	REG02	0.9334	0.0013	0.0864	0.0008
	REG03	0.8824	0.0015	0.0818	0.0011
	EDU04	0.9979	0.0004	0.0949	0.0000
	EDU05	0.9981	0.0003	0.0955	0.0001
	EDU06	0.8149	0.0014	0.0806	0.0003
	EDU07	0.9934	0.0001	0.0953	0.0000
	INN08	0.9898	0.0004	0.0946	0.0002
	INN09	0.9945	0.0004	0.0948	0.0001
	INN10	0.8967	0.0007	0.0831	0.0003
	ICT11	0.9869	0.0001	0.0952	0.0001
	ICT12	0.9905	0.0002	0.0952	0.0000
ED	LED01	0.8400	0.0189	0.2276	0.0362
	LED02	0.9399	0.0166	0.2672	0.0614
	LED03	-0.4341	0.0322	-0.1510	0.0760
	LED04	-0.8598	0.0216	-0.2159	0.0703
	LED05	-0.9457	0.0249	-0.2490	0.0334

Source: own calculations

Other results are consistent with expectations. Stimulants have positive weights and loadings and destimulants have negative ones.

Equations (3) and (4) present estimations of internal relations. Standard deviations calculated basing on Tukey cut method are given in brackets.

$$\hat{KBE} = 0.1984REG + 0.3623EDU + 0.2661INN + 0.1851ICT - 0.0999 \qquad (3)$$
$$\;\;\;\;\;(0.0084)\;\;\;\;\;\;\;\;(0.0024)\;\;\;\;\;\;\;\;(0.0105)\;\;\;\;\;\;\;\;(0.0043)\;\;\;\;\;\;\;\;(0.1244)$$

$$\hat{ED} = 0.9733KBE - 2.2056 \qquad (4)$$
$$\;\;\;\;(0.0131)\;\;\;\;\;\;\;\;(1.9218)$$

Signs of estimators are consistent with expectations. Moreover, all latent variable are statistically significant ("2s" rule). Coefficient of determination (R^2) has value 1.0 for the equation (3) and value 0.95 for the equation (4). General Stone-Geisser test is equal to 0.73[7]. The model can be verified positively.

All four pillars influence positively the level of KBE. The strongest impact has pillar "education and training" (0.3623), the lowest – "information infrastructure" (0.1815). Furthermore, equation (4) shows that correlation between the level of KBE development and the level of economic development is positive and strong.

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[7] Stone-Geisser test measures prognostic property of soft model. Its values are in the range from -∞ to 1. Positive (negative) value of this test indicates high (poor) quality of model.

CONCLUSIONS

Partial Least Squares method gives estimates of values of KBE latent variable (Figure 2). They can be used to analyze changes in the level of KBE development.
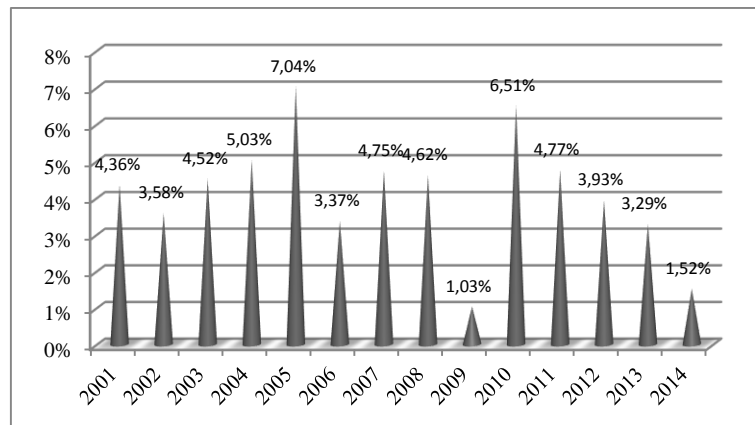
Figure 2. The values of synthetic measure of KBE latent variable
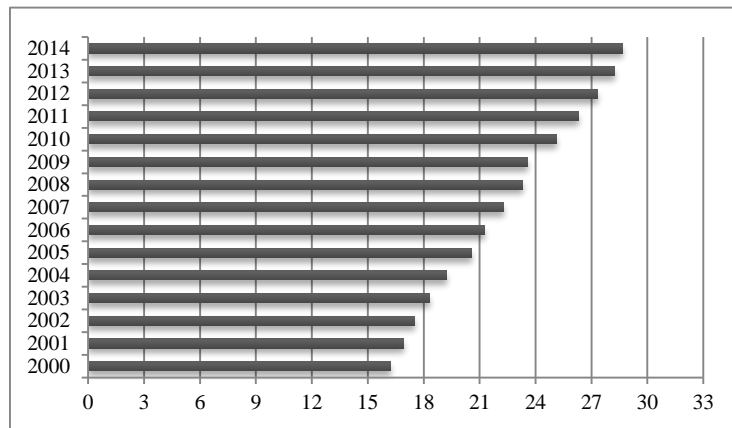
Source: own calculations

The annual rate of change is presented on Figure 3. In the period 2000-2014 KBE grew at an average rate 4% per year. The highest growth took place in 2005 (7.04%), the lowest – in 2009 (1.03%).

Figure 3. The annual rate of change in the level of KBE development in European Union, 2000-2014

Source: own calculations

REFERENCES

APEC Economic Committee (2000) Towards Knowledge-based Economies in APEC.

Becla A. (2010) Wady i zalety metody KAM (Knowledge Assessment Methodology) służącej do identyfikacji poziomu zaawansowania gospodarki opartej na wiedzy, Prace Naukowe UE we Wrocławiu, nr 139, Wrocław.

Chen D. H. C., Dahlman C. J. (2005) The Knowledge Economy, the KAM Methodology and World Bank Operations, World Bank Institute, D.C. 20433, Washington, http://siteresources.worldbank.org/INTUNIKAM/Resources/2012.pdf.

Dworak E. (2014) Gospodarka oparta na wiedzy, innowacyjność i rynek pracy, Wydawnictwo UŁ, Łódź.

European Commission (2005) Working together for growth and jobs – A new start for the Lisbon Strategy, Communication to the Spring European Council, Brussels.

European Commission (2010) Europe 2020, A European strategy for smart, sustainable and inclusive growth, Brussels.

OECD (1996) The Knowledge-based Economy, Paris.

OECD, World Bank (2001) Korea and Knowledge-based Economy, Making the Transition, Paris.

Perło D. (2004) Źródła finansowania rozwoju regionalnego, Wydawnictwo Wyższej Szkoły Ekonomicznej w Białymstoku, Białystok.

Piech K. (2009) Wiedza i innowacje w rozwoju gospodarczym: w kierunku pomiaru i współczesnej roli państwa, Instytut Wiedzy i Innowacji, Warszawa.

Rogowski J. (1990) Modele miękkie. Teoria i zastosowanie w badaniach ekonomicznych, Wydawnictwo Filii UW w Białymstoku, Białystok.

Skrodzka I. (2015) Kapitał ludzki polskich województw – koncepcja pomiaru, Wydawnictwo Uniwersytetu w Białymstoku.

Wold H. (1980) Soft Modelling: Intermediate between Traditional Model Building and Data Analysis, Banach Centre Publication 6, Mathematical Statistics.