ЕКОНОМІКА ТА УПРАВЛІННЯ НАЦІОНАЛЬНИМ ГОСПОДАРСТВОМ

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CLUSTERING OF COUNTRIES IN GLOBAL LANDSCAPE OF KNOWLEDGE ECONOMY DEVELOPMENT

Urgency of the research *stems from the need to analyse the complex transformation processes in the world economy system, associated with transition to knowledge economy (KE). Identifying the distinctive features of the countries at the national level is a key prerequisite for generalization of these processes at the global level.*

Target setting. *In the context of changes in the world economy, an assessment of the level and dynamics of KE development parameters in general and by individual components is critical for every country. International comparative analysis allows assessing the global landscape of KE development as well as identifying its key factors.*

Actual scientific researches and issues analysis. *Prominent Ukrainian and foreign scientists-economists formed the theoretic and methodological bases for the study. Numerous studies prove the relevance of the selected topic and significance of the identified scientific and practical problem.*

Uninvestigated parts of general matters defining. *Global landscape of KE development has been studied in a fragmented manner. In particular, it is related to search for its structure and identification of the key factors of knowledge management.*

The research objective. *To implement clastering of countries using KE development parameters and to identify its key factors.*

The statement of basic materials. *Clustering of countries has been implemented using KE development parameters in 2010 and 2014, including such components as education, science, information and communication technologies, manufacturing technologies and innovative business. Based on the assessment of differences between clasters, we have identified the key factors of KE formation. Boundary values of these parameters by clusters enabled us to evaluate a position of Ukraine in the global landscape.*

Conclusions. *Study outcomes characterize the structure and heterogeneity of the global landscape of KE development. We have identified its key factors, boundary values, which are critical while assessing a position of particular countries and identifying target indicators of their strategies.*

Keywords: *knowledge economy; world economy; cluster analysis.*

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КЛАСТЕРИЗАЦІЯ КРАЇН У ГЛОБАЛЬНОМУ ЛАНДШАФТІ РОЗВИТКУ ЕКОНОМІКИ ЗНАНЬ

Актуальність теми дослідження *зумовлена необхідністю аналізу процесів комплексної трансформації світогосподарської системи, пов'язаної з переходом до економіки знань (ЕЗ). Виявлення країнових особливостей на національному рівні виступає важливою передумовою узагальнення цих процесів на глобальному рівні*

Постановка проблеми. *У контексті світогосподарських змін для кожної країни є важливою оцінка рівня і динаміки параметрів розвитку ЕЗ загалом та за окремими компонентами. Проведення міжнародного компаративного аналізу дозволяє оцінити глобальний ландшафт розвитку ЕЗ, а також визначити її ключові фактори.*

Аналіз останніх досліджень і публікацій. *Теоретико-методологічні засади дослідження ЕЗ були закладені провідними закордонними та українськими вченими-економістами. Численні дослідження підтверджують актуальність обраної теми та важливість окресленої науково-практичної проблеми.*

Виділення недосліджених частин загальної проблеми. *Глобальний ландшафт розвитку ЕЗ досліджено фрагментарно. Це, зокрема, стосується пошуку його структури і визначення ключових факторів ЕЗ.*

Постановка завдання. *Здійснити кластеризацію країн за параметрами розвитку ЕЗ та визначити її ключові фактори.*

Виклад основного матеріалу. *Виконано кластеризацію країн за параметрами розвитку ЕЗ у 2010 та 2014 рр., включаючи такі її складові як освіта, наука, ІКТ, виробничі технології, інноваційний бізнес. На основі оцінки відмінностей між кластерами визначено ключові фактори становлення ЕЗ. Граничні значення цих параметрів за кластерами дозволили оцінити позиції України у глобальному ландшафті.*

Висновки. *Результати дослідження характеризують структуру і неоднорідність глобального ландшафту розвитку ЕЗ. Визначено її ключові фактори, граничні значення яких важливі при оцінці позицій окремих країн та встановленні цільових індикаторів їх стратегій.*

Ключові слова: *економіка знань; світове господарство; кластерний аналіз.*

Urgency of the research. In the early XXI century, the signs of global structural crisis of the world economy have been observed, which was a result of the accumulated problems, inherent in the modern economic model in a general sense, and it marked a completion of the previous long-wave cycle.

A complex transformation of the world economic system, related to transition to the more advanced type of economy – knowledge economy (KE) as the higher level of reproductive evolution, started in the context of transition to a new cycle, launched by the forth industrial revolution. Knowledge becomes the most critical resource in the economy of such type and it enables humans to better organize and support their vital activities, in particular, economic management, especially considering the growing demands and exacerbation of resource limits.

A top-priority challenge to build the KE has emerged at the national level and it has become a subject to state strategies for social and economic development of multiple countries of the world in the context of the world economy transformation. The transformations, related to building of KE, are formed at the country level, where certain asymmetries and specific characteristics become apparent. Therefore, from the perspective of studying the global landscape of KE development, it is particularly important to analyze similarities and differences of the countries, to divide them into groups (clusters) based on a wide range of parameters and to provide insight into the formation of a new type of the economy.

Target setting. Most countries of the world more or less use the KE concept while elaborating the strategies of social and economic development and well as while implementing structural and institutional transformations. Taking it into consideration, a complex assessment of the level and dynamics of KE development parameters is critical for every country. Such scientific and practical problem also arises in the world-level studies, in particular, within the framework of international comparison, and it can be addressed using cluster analysis. At the same time, generalization of a wide range of parameters, representing such complex matter as KE and its multiple components, is of particular importance. Clustering of countries will make it possible to obtain the structure of global landscape of KE development as well as qualitatively and quantitatively to assess the progress towards a new paradigm. Searching for similarities and differences of countries, we can also identify the key factors of KE formation, determining positions of individual countries.

Actual scientific researches and issues analysis. Theoretic and methodological bases for study of KE were laid by such internationally recognized scientists as: P. Drucker, B.-A. Lundvall, F. Machlup, R. Solow, J. Stiglitz, F. von Hayek and others. Their best practices, being reconsidered and supplemented, can be productively used while studying modern processes at the national and global levels. The leading Ukrainian economists made a significant contribution into study of knowledge economy, in particular: O. Amosha, O. Belorus, A. Galchinsky, V. Heyets, I. Kalenyuk, D. Lukyanenko, V. Sidenko, L. Fedulova, A. Filippenko, A. Chukhno and others.

We would like to highlight a few scientific publications, proving the urgency of this paper topic and nature of the problem. Thus, O. Belorus lays the emphasis on the processes of reproductive evolution and structural transformation [1], which give rise to challenges and define the focus of analytical studies of changes in the world economy, in particular, related to KE development. Kh. Kyrylych stresses the problem of uneven development of the world economy [2], which makes the objective, related to assessment of similarities and differences of countries, i.e. clustering, more complicated and relevant. The paper of I. Kalenyuk and L. Cimbal emphasizes the importance of studying the KE development that, in particular, is attributable to a new paradigm and determinants of the world leadership [3]. The papers of M. Kaur and L. Singh [4] and R. Vadra [5] prove the importance of such study for the developing countries. The assessment of global landscape of KE development becomes more relevant. In recent years, there have been published numerous papers (in particular, P. Altbach [6]), which suggest examining the global knowledge economy. Therefore, the tasks of assessing the global landscape of KE development as a new dimension of international comparisons are actualized.

Uninvestigated parts of general matters defining. It should be noted that, despite of the close attention to assessment of modern transformations of the world economy, the processes of KE development at the global level are studied quite fragmentarily. Among other things, it is related to search for the structure of global landscape of KE development, assessment of general progress of the countries and identification of the most important factors.

The research objective. The objective is to implement clustering of countries using KE development parameters, facilitating assessment of the global landscape of the respective processes and

identification of the key factors of formation of this type of economy.

The statement of basic materials. For the purposes of cluster analysis it is required to identify the parameters, characterizing formation of KE. In our point of view, KE is mostly represented by a unity of such elements as: education, science, information and communication technology (ICT), production technologies and innovative business.

The target of clustering is to identify objectively the existing clusters (groups) of countries with similar value of parameters for KE development, based on the available multidimensional input data. Clustering will enable us: 1) to divide countries into clusters according to qualitative and quantitative parameters for KE development to enhance quality of studies; 2) to identify distinctive features of each of the clusters; 3) to highlight distinctive features of different clusters, thereby identifying the key factors of KE and their boundary values by clusters, which characterize transition to this kind of economy. The results of clustering will outline the concept of KE development at the global level.

Clustering is one of the targets of Data Mining, implying division of a set of homogeneous objects, characterized by input vectors, into clusters according to the degree of their similarity. Every cluster is formed in such a way that the objects, composing it, are the most similar to each other and are not similar to the objects, included into the other clusters. This forms the basis for comparison of clusters and identification of differences between these clusters and the countries, included into the clusters.

Distribution of countries by clusters is performed based on the data, characterizing individual components of KE. A set of data is formed based on official statistical reports, provided by international organizations, as well as well-recognized international ratings and indicators. Data is distributed across five analytical columns, according to understanding of KE, where the measurement indicators are structured (Tab. 1).

Table 1

Indicators for clustering of countries by the parameters of KE development that are structured by analytical columns

Columns				
Education	Science	ICT	Production Technologies	Innovative business
1. Government expenditure on education, total (% of GDP); 2. Gross enrolment ratio, tertiary, both sexes (%) [1]; 3. Higher education and training (Global Competitiveness Index, World Economic Forum); 4. Expected years of schooling (Human Development Index, United Nations Development Programme); 5. Mean years of schooling (Human Development Index, United Nations Development Programme).	1. Research and development expenditure (% of GDP); 2. Researchers in R&D [2] (per million people); 3. Scientific and technical journal articles; 4. Citable documents; 5. Patent applications, residents; 6. Patent grants, residents	1. ICT service exports (% of service exports, BoP); 2. ICT goods exports (% of total goods exports); 3. Networked Readiness Index (World Economic Forum); 4. ICT Development Index (International Telecommunication Union).	1. High-technology exports (% of manufactured exports); 2. Economic Complexity Index (ECI) (Center for International Development at Harvard University) 3. Technological readiness (Global Competitiveness Index, World Economic Forum).	1. Ease of Doing Business Ranking; 2. Business sophistication (Innovation and Sophistication Factors Subindex) (Global Competitiveness Index, World Economic Forum); 3. Innovation Input Sub-Index (Global Innovation Index, World Intellectual Property Organization and INSEAD); 4. Innovation Output Sub-Index (Global Innovation Index, World Intellectual Property Organization and INSEAD).

[1] Gross enrollment ratio is the ratio of total enrollment, regardless of age, to the population of the age group that officially corresponds to the level of education shown. [2] R&D – Research and Development

Sources: The World Bank Group // *https://data.worldbank.org*; Center for International Development at Harvard University // *http://atlas.cid.harvard.edu*; World Economic Forum // *http://www.weforum.org*; The Global Innovation Index // *https://www.globalinnovationindex.org*. United Nations Development Programme. Human Development Reports // *http://hdr.undp.org*. SCImago Journal & Country Rank // *http://www.scimagojr.com*; International Telecommunication Union // https://www.itu.int; World Intellectual Property Organization // *http://www.wipo.int/portal/en/index.html*.

ЕКОНОМІКА ТА УПРАВЛІННЯ НАЦІОНАЛЬНИМ ГОСПОДАРСТВОМ

Proceeding from the specifics of data set, for clustering of countries we chose *k-means* algorithm, being the most efficient, when data creates compact bunches in the multidimensional indicators space, which are very different from each other. The algorithm consists of the following steps:

1. *k* of initial centers of future clusters is chosen randomly (*k* – is a number of clusters);
2. The algorithm includes each selected object into the cluster, having the closest center according to the chosen metrics;
3. Mass centers of the created clusters (μ_i) are recalculated according to the formula

$$\mu_i = \frac{1}{|s_i|}\sum_{x_j \in S_i} x_j,$$

where S_i – obtained clusters, $i = 1,2,\ldots, k$;
x_j – j parameter, $x_j \in S_i$.

4. We calculate the total squared deviation of cluster points from centers of these clusters:

$$D = \sum_{i=1}^{k}\sum_{x_j \in S_i} \rho(x_j, \mu_i)^2,$$

where ρ – chosen metrics.

A criterion of objects similarity is a distance between the objects. Euclidean space was chosen as metrics. It is a geometric distance between points in multidimensional (Euclidean) space and a pair of points $p=(p_1,\ldots,p_n)$ and $q=(q_1,\ldots,q_n)$, which is calculated according to the formula:

$$d(p,q) = \sqrt{(p_1 - q_1)^2 + (p_2 - q_2)^2 + \cdots + (p_n - q_n)^2}.$$

The algorithms are committed to minimize the total squared deviation of cluster points from centers of these clusters. *k-means* algorithm for Euclidean metrics looks like this:

$$D = \sum_{i=1}^{k}\sum_{x_j \in S_i}(x_j - \mu_i)^2.$$

5. Steps 2-4 are repeated iteratively until the value of the total squared deviation stops changing. The total squared deviation is a functional of this algorithm quality.

In order to obtain tangible results, we made audit of data quality and defined the number of clusters for this sample. It was carried out using the scaling method, which allows us, having a few deviations, to maintain basic structural relationships between objects of different clusters. It has been determined that the optimal number is four clusters.

It should be taken into consideration that since the very beginning the selection of countries has not included the countries with the lowest indicators for all components of KE that is often caused by weakness or a lack of scientific and technological potential as well as a lack of complete set of data.

Clustering was carried out using the data analyzing software of the portal Science Hunter (URL: http://sciencehunter.net.). Its results for 2014 are shown in the Tab. 2 (in comparison with clustering according to data of 2010, Serbia and Turkey moved from IV to III cluster).

Table 2

Results of clustering of countries according to parameters for KE development

Cluster	Countries
I	USA, China, Japan;
II	Australia, Austria, Belgium, Great Britain, Germany, Denmark, Israel, Ireland, Canada, the Republic of Korea, the Netherlands, New Zealand, Norway, Slovenia, Finland, France, Switzerland, Swiss, Estonia;
III	Argentina, Bulgaria, Hungary, Greece, Spain, Italy, Latvia, Lithuania, Poland, Portugal, Romania, Serbia, Slovakia, Turkey, Ukraine, Croatia, Czech Republic, Chile;
IV	Brazil, India, Indonesia, Malaysia, Mexico.

The assessment, based on the absolute and relative indicators, allowed singling out the USA, China and Japan into a separate cluster as the countries with the strongest economies of the world. The USA and Japan are the undoubted leaders according to a majority of absolute indicators and multiple relative indicators of KE and, at the same time, they demonstrate positive dynamics. These countries should be considered as the countries, which have achieved such quality as KE. Concerning China, they are significantly ahead of other countries according to absolute indicators and they are a little bit behind (and often even ahead of) the rest of countries according to a number of relative indicators. Besides, China intensively builds up parameters of all components of KE. In scientific and technological aspects China approaches the level of quality, corresponding to KE. In general, the countries of I cluster have the highest absolute positions in respect of KE development in the world.

The countries of II cluster are essentially similar to each other by the structure of economy, relative and multiple absolute parameters of KE development. In general, these countries can be considered as the countries, which have achieved or are close to achievement of the quality of development, typical of KE. It is proven by the overall level and positive dynamics of the indicators. The countries of II cluster are behind the USA, Japan and China according to the level of some absolute indicators that can be explained by objective circumstances. At the same time, a number of countries of II cluster are the world leaders in science and some fields of technology, which, in particular, is related to: Germany, the Republic of Korea, France, Israel, Switzerland, etc. These countries have even more balanced combination of KE components than the countries of I cluster.

II cluster is formed by the countries with modern mixed economy, cutting-edge technology, high level of scientific and educational development and business innovative activity. In aggregate these countries also play the leading role in transformation of the world economy. Besides, the countries of this cluster are of interest for study of: 1) rapid progress (Israel, the Republic of Korea, and Ireland); 2) successful introduction of market model for acceleration of technological development (Estonia and Slovenia); 3) transition of the developed raw material producing countries to KE (Australia, Canada, Norway, New Zealand); 4) building of inclusive science intensive economies, having no heavy industry (Denmark, Israel, Finland, Belgium). II cluster is the most interesting for Ukraine and therefore, parameters of countries from this cluster can serve as a basis for establishment of target indicators or guidelines.

III cluster is quite varied. A number of countries (Argentina, Turkey and Chile) have undergone industrialization stage for the previous years and some countries (Greece, Spain, Italy and Portugal) are now experiencing a long-term recession after the crisis of 2008-2009. A majority of countries (Bulgaria, Hungary, Latvia, Lithuania, Poland, Romania, Serbia, Slovakia, Croatia, Czech Republic) – are the countries, which carried out successful transformations after the collapse of socialist system and are now developing within the framework of European structures. This cluster has also integrated currently quite successful countries (for instance, Poland and Chile) as well as the countries, which do not show extraordinary progress. In general, these countries are significantly behind the countries from I and II clusters.

Due to objective reasons, the countries of IV cluster have lower indicators of all KE components than the countries of previous clusters. At the same time, every country of the IV cluster demonstrates considerable achievements in certain spheres, taking into account their actual state of affairs. These countries also have a huge potential for economic growth, therefore they are interesting in terms of studying the processes of KE formation.

The analysis confirmed the objectivity of the clustering of countries. The objective to find differences between clusters enabled us to form training sampling that, being classified, makes it possible to identify the key features of the countries of each cluster as well as distinctive features between clusters (classes). In fact, the analysis allows identifying the key factors of KE as far as the boundary values of certain parameters, separating some classes from the others, thereby actually act as the development framework of KE in qualitatively different groups of countries. A positive feature of this analysis is that the aspects, which require enhanced development as well as parameter values, which have to be achieved, become evident for every individual country.

For classification, aimed at identifying the key factors, we used structural-logical methods for training sample, which allow performing qualitative assessment of the significance of individual parameters

as well as groups of indicators and enable us to find differences between the identified classes (clusters). *x* parameter (attribute) means discrete description (probably, modified quantitative or qualitative description) of one or another feature of the object under study. In its turn, *X* object, from our perspective, is described using a set ($x_1, ..., x_n$) of discrete values of x_i parameters (attributes) in the space of parameters (attributes) with a dimension of *n*, where the values (attributes) of these parameters are set along its axes $x_1, x_2, ..., x_n$. Therefore, a description of the object *X* will mean a set $X = (x_1, ..., x_n)$ of discrete values of parameters (attributes), hereinafter referred to as the discrete set *X*.

Training sample is represented in the form of table of empirical data, consisting of a multitude of verified discrete sets *X*, i.e. the sets, where we know their belonging to one or another class, given in this sample. Inclusion of certain parameters has been assessed using the following formula:

$$V(x_{i1}, \dots, x_{ij}) = \frac{1}{k}\sum_{\Delta \in \Gamma} max_Y\left(\frac{m_{\Delta Y}}{m_Y}\right), \quad (1)$$

where *k* – number of classes (clusters);

m_Y – number of objects, belonging to class (cluster) *Y*;

$\Delta = t_{i1}, t_{i2}, \dots, t_{ij}\ (0 \le t_{ij} \le k_{ij}-1),\ j=1, \dots, \gamma$ – arbitrary set of parameter (attribute) values $x_{i1}, ..., x_{ij}\ (1 \le \gamma \le n)$;

$m_{\Delta Y}$ – amount of sets of training sample of *m* class, that the following relation is applied to $x_{ij}=t_{ij}\ (j=1, \dots, \gamma)$, t_{ij} – value of parameters (attributes) x_{ij} in a set Δ, Γ – a multitude of all sets of parameter (attribute) values $x_{i1}, ..., x_{ij}$.

We can show that $1/k \le V(x_{i1}, ..., x_{ij}) \le 1$. This assessment takes on boundary value that is equal to 1 in case of absolute difference between classes. It is important to note that such assessment is calculated, directly based on data of training sample and characterizes it as the resolving power. In our training sample we use 22 parameters, characterizing KE development. In boundary case, even if we use just binary encoding of data, required to simplify solution for classification of training sample, a search for the groups of key factors (parameters) would require verification of 2^{22} different combinations of factors, i.e. four millions of their varied combinations. Manual verification of all these combinations is simply impossible. Application of the assessment (formula 1) and the algorithm for search of the informative groups of parameters allows us considerably to shorten the above-stated enumeration. Using the software, which allows implementing the aforementioned algorithm and is available on the portal Science Hunter (URL: http://sciencehunter.net), we have obtained the following group of factors, which can be called the key one as far as the values of these factors significantly differ in the countries, included into different clusters. Therefore, these factors can serve as indicators of KE development in one or another group of countries and can be called the key factors.

Analysis of the data for 2010 enabled us to identify the following key factors of KE:

1 – *Gross enrolment ratio, tertiary, both sexes (%)* – this indicator naturally proves the growing importance of the higher education as well as the necessity to “enroll” there the entire population of the country aiming to build knowledge economy;

2 – *Mean years of schooling* – the key role of this indicator is also explained by significance of education, but, at the same time, duration of study becomes essential, where its increasing becomes the prerequisite for formation of the high level of human resources. The importance of the duration of study is significantly growing in the period of technological changes, when it is necessary to master new technologies and continuously to educate human resources. First of all, this is required by modern industrial revolution and digital transformations.

As it has been established in XX century, the indicators of education continue to be the most critical parameters, dividing countries by the level of social and economic development. A priority of education does not disappear even today, when a new type of economy is created based on the human intellectualized capital;

3 – *Patent applications, residents* – this indicator demonstrates the activity of scholars and innovators as well as overall performance of R&D in a particular country. The growing number of applications is reasonable in conditions technological changes. The importance of this indicator stems from the necessity to enhance scientific and technological activities in an effort to generate innovations in the

beginning of the new economic wave;

4 – *Innovation Input Sub-Index* – this subindex of the Global innovative index is complex and it encompasses a number of components (institutes, human capital and studies, infrastructure, marketing sophistication, business sophistication). The key importance of this indicator stems from the importance of innovative capability.

Thus, the given indicators for 2010 in aggregate have divided the obtained clusters of countries. All these indicators are essential for KE separately as well as jointly, when the synergetic effect is produced. Overall significance consists, first of all, in sharing knowledge, increasing the quality of human resources and creating the preconditions for innovations. Tab. 3 shows maximum and minimum values of key indicators, according to the obtained clusters of countries.

Table 3

Boundary values of basic parameters that the clusters of countries are distributed by, according to development of KE components, 2010

	Gross enrolment ratio, tertiary, both sexes (%)		Mean years of schooling, years		Patent applications, residents, units		Innovation Input Sub-Index	
	min	max	min	max	min	max	min	max
Cluster I	58,011	80,917	7,5	12,4	241977	293066	3,64	5,4
Cluster II	52,793	99,660	9	12,6	84	131805	4,52	5,54
Cluster III	54,672	102,731	8	12,3	108	8877	3,44	4,45
Cluster IV	17,9115	55,999	4,4	9,5	290	8853	3,51	4,51
Ukraine	***81,934***		***11,3***		***2556***		***3,6***	

Ukraine demonstrates high level of *Gross enrolment ratio, tertiary, both sexes* and *Mean years of schooling*. However, it should be noted that the quality of higher education is much lower than in the developed countries, and the duration often depends on labor market problems. According to the number of *patent applications*, Ukraine is closer to the countries of III and IV clusters, but, in respect of conditions, we demonstrate quite high level of potential. The assessment of preconditions for innovations (*Innovation Input Sub-Index*) is close to the bottom boundary of III and IV clusters (as well as the indicator of China).

In 2014 the following factors became the key factors of KE:

1 – *Gross enrolment ratio, tertiary, both sexes (%)* and 2 – *Mean years of schooling* – the fact that these parameters are still in the list of key factors proves the importance of education for knowledge economy;

3 – *Patent grants, residents* – this parameter demonstrates activity of scholars and innovators as well as overall performance of R&D in the country. Like in case of patent applications, the importance of this indicator stems from the necessity to enhance scientific and technological activities in an effort to generate innovations. The significance of efficiency in conditions of technological changes in the countries of I and II clusters has increased;

4 – *Networked Readiness Index*– this parameter demonstrates the importance of ICT. Probably, the key role of this indicator was identified through building of information society and digital economy in the leading countries as well as formation of new models of industrial production, where ICT is an integral part, which became a practical basis of modern economy;

5 – *Technological Readiness* – the importance of this factor and its transformation into the key factor, probably, stems from the growth of technological significance in the context of industrial revolution.

Therefore, in 2014 these indicators in aggregate divided the obtained clusters of countries. All these factors are also critical for KE, both individually and jointly, having a common significance in synergy. Tab. 4 shows maximum and minimum values of key indicators, according to the obtained clusters of countries in 2014.

In 2014 Ukraine has higher value of the indicator *Gross enrolment ratio, tertiary, both sexes (%)*. By this indicator Ukraine significantly exceeds the bottom boundaries of II and II clusters and even exceeds the lower threshold of the first cluster. A situation with the parameter *Mean years of schooling* is almost the same and it even more exceeds the bottom boundary of cluster I. At the same time, the

ЕКОНОМІКА ТА УПРАВЛІННЯ НАЦІОНАЛЬНИМ ГОСПОДАРСТВОМ

lowest quality of education in Ukraine should be taken into consideration, as well as remoteness of the value from the upper threshold of I, II and III clusters. By the quantity of *Patent grants, residents*, Ukraine exceeds the bottom boundaries II, III and IV clusters, but we are significantly behind III cluster, and by 57 times lower than the upper boundary of II cluster. By *Networked Readiness Index* the Ukrainian value is considerably lower than the upper boundary of all clusters. Moreover, Ukraine has not even reached the bottom boundary of II cluster. By parameter *Technological Readiness* Ukraine is on the bottom boundary of III cluster and is far from the upper boundary of all clusters. *Technological Readiness* is the "weakest" point of Ukraine among the key factors of KE building.

Table 4

Boundary values of basic parameters that the clusters of countries are distributed by, according to development of KE components, 2014

	Gross enrolment ratio, tertiary, both sexes (%)		Mean years of schooling, years		Patent grants, residents, items		Networked Readiness Index		Technological readiness	
	min	max	min	max	min	max	min	max	min	max
Cluster I	79,99	90,31	7,5	12,9	144621	177750	4,05	5,61	3,53	5,78
Cluster II	56,48	94,21	10,3	13,1	26	97294	4,6	6,04	5,05	6,28
Cluster III	52,92	113,87	7,6	12,4	6	6863	3,53	4,78	3,5	5,42
Cluster IV	25,54	49,28	5,4	10	223	720	3,85	4,83	2,75	4,21
Ukraine	***82,305***		***11,3***		***1701***		***3,87***		***3,5***	

Conclusions. Therefore, the analysis that was performed made it possible to distribute countries by four clusters, characterizing the structure and heterogeneity of global landscape of KE development. The obtained clustering has demonstrated the objective picture of similarities and differences between countries that has been used as a basis for identifying the key KE factors and their boundary values by clusters. Based on this data, we have made assessment of the countries positions that enables us to identify target indicators while developing the strategies of their social and economic development, focusing on individual components of KE. In further studies we are going to focus on assessment of synchronism in transition of individual groups of countries to knowledge economy.

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