

RESEARCH OF ECONOMIC GROWTH IN THE CONTEXT OF KNOWLEDGE ECONOMY

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doi:10.13165/IE-14-8-1-08

Abstract. This paper analyses the nature of economic growth in the context of knowledge economy. Indicators that can describe the individual components of knowledge economy are selected. The dynamics of knowledge economy components based on statistics of Ukraine, Poland, Germany and Lithuania is researched. The neural network was built using knowledge economy indicators based on time series data for the years 1996-2011s. The constructed neural network can be used for developing models for economic growth forecasting.

JEL classification: O11, O300, E27.

Keywords: economic growth, knowledge-based economy, neural networks.

Reikšminiai žodžiai: ekonomikos augimas, žinių ekonomika, neuroniniai tinklai.

Introduction

Economic growth is an important macroeconomic category, which is an indication not only of absolute increase in social production, but also the ability of the economic system to meet the growing needs and improve life quality.

Current stage of global economic development is characterised by gradual increase in the level of intellectualisation and the transition to an economy based on knowledge. This position of many countries has contributed to the priority development of their information production, much higher level of economic and social development compared to other countries. And this trend must be considered in determining the strategic outlook of the domestic economy in the direction of the transition to a knowledge-based economy,

which will ensure its competitiveness and the need to intensify the knowledge factor of economic growth in Ukraine. Consequently, economic growth will depend on the available knowledge creation and its ability to multiply.

The object of this paper is economic growth in the context of knowledge economy.

The aim of this work is the research of economic growth in the context of knowledge economy, analyse the components of knowledge economy and its impact on economic growth by using neural networks.

The aim is achieved by means of the following key tasks:

- explore the concept of economic growth in the context of knowledge economy;
- research the dynamics of knowledge economy components;
- justify the need to study the relationship of GDP and knowledge economy components;
- analyse the impact of knowledge economy components that affect the size of GDP.

1. The concept of economic growth in the context of knowledge economy

Economic growth is a central social and economic problem faced by all countries. According to the economic growth dynamics, we can analyse the development of national economies, the standards of living, solving of limited resources problem. This is the main indicator of development and prosperity of any country and one of the main macro-economic objectives.

System alignment and balance of sustainable development principles (economic, environmental and social principles) is the task of enormous complexity and one of the main challenges all over the world. In recent years, the role of knowledge in economic development is growing ahead of the significance of production and natural resources.

Economic growth increasingly depends on the ability to acquire new knowledge and apply it in all areas of life. Relocation of scientific knowledge at the centre of the key factors for sustainable economic growth caused concentration-date research on the problem of becoming a knowledge economy.

Knowledge economy is a complex and multifaceted phenomenon that has attracted and continues to attract the attention of many researchers. Thousands of publications that explored different aspects of knowledge economy, hundreds of conferences around the world on this issue have demonstrated the relevance of this issue.

Various observers describe today's global economy as one in transition to a "knowledge economy", or an "information society". However, the rules and practices that determined success in the industrial economy of the twentieth century need rewriting in an interconnected world where resources, such as know-how are more critical than other economic resources. This briefing highlights recent thinking and developments and offers guidance on developing appropriate organisational strategies to succeed into the new millennium. It summarises key conclusions from our trends database and research analysis (Skyrme, 1997).

OECD's experts are increasingly concerned with understanding the dynamics of the knowledge-based economy and its relationship with traditional economics, as reflected in the "new growth theory". Growing codification of knowledge and its transmission through communications and computer networks has led to the emerging "information society". The need for workers to acquire a range of skills and to continuously adapt these skills underlies the "learning economy". The importance of knowledge and technology diffusion requires better understanding of knowledge networks and "national innovation systems". Most importantly, new issues and questions are raised regarding the implications of the knowledge-based economy for employment and the role of governments in the development and maintenance of the knowledge base (OECD, 1996).

Debra M. Amidon, Piero Formica, and Eunika Mercier-Laurent explored that knowledge economy is the use of knowledge (*savoir, savoir-faire, savoir-être*) to generate tangible and intangible values. Technology and in particular knowledge technology (Artificial Intelligence) helps transform a part of human knowledge to machines and this knowledge can be used by decision support systems in various fields and generate economic values. Knowledge economy is also possible without technology. They also researched the principles and standards, practices, policy, governance and measurement of Knowledge Economics (Amidon, 2005).

One of the directions of knowledge economy study is the formation of monitoring systems of knowledge economy development. Among the existing approaches of knowledge economy analyses, one of the most popular approaches is related to the integral indices construction. Integral index is a weighted aggregate indicator, which is composed of a number of indicators and selected based on the goals and objectives of the study. On a nationwide scale, the following indicators allow comparing the levels of development of individual indicators that form the state of knowledge economy. International organisations use integrated indices for comparison and construction of the ranking of countries and regions in terms of development.

The most famous of integrated approaches to knowledge economy measurement is the approach proposed by the World Bank as part of the special programme "Knowledge for Development" (Knowledge for Development Program, K4D) (Chen, 2005). The experts of the World Bank have developed a methodology for the assessment of knowledge economy (Knowledge Assessment Methodology, KAM), which is based on the idea that the transition to becoming a knowledge economy requires the development of long-term strategies, which should focus on the development of its four components¹:

1. The economic incentive and institutional regime that provided economic policies and institutions that can effectively mobilise and allocate resources, encourage creativity and motivate for the effective creation, distribution and prevalence of use of existing knowledge (Economic Incentive Regime Index).

2. Educated and skilled workers (labour) which can continuously upgrade and adapt their skills to effectively create and use knowledge (Education Index).

3. An effective innovation system, consisting of firms, research centres, universities, consulting firms and other organisations that accept and adapt global knowledge to local needs, and create new knowledge and because of it – new technologies (Innovation Index).

¹ http://info.worldbank.org/etools/kam2/KAM_page5.asp

4. Modern information infrastructure that provides effective transmission, distribution and processing of information and knowledge (Information and Communication Technology Index).

Analysis of publications and research shows great interest of the scientific community in the nature and certainty of the key features of knowledge economy, it is global and one of the most important areas of public policy in all developed countries. Within this are the following research areas of knowledge economy, in particular:

- the innovative nature of knowledge economy (Karlsson, 2011; Wolfe, 2006; Heyets, 2006; Yakovenko, 2010);
- the impact of information and communication component of country competitiveness (Ivanova, 2008; Daley, 2000);
- summarise the relationship of the knowledge economy and public policy in order to increase efficient use of economic resources (Dyehtyar, 2011);
- human potential development as a structural component of the knowledge economy (OECD (1996); Zadorozhnyy, 2009);
- different approaches to measuring knowledge economy based on the calculation of integral indices (KEI and KI Indexes; OECD, 1996; Zhukovych, 2013), etc.

However, many issues require further study, including the analysis of the components of knowledge economy and its impact on economic growth, the formation of a decision-support system for the management indicators that form the appropriate components of knowledge economy for long-term economic growth of any country.

2. Research of the dynamics of knowledge economy components

As noted above, one of the main research areas of knowledge economy is to assess knowledge economy through an approach proposed by the World Bank (Knowledge Assessment Methodology, KAM). The KAM Knowledge Index (KI) measures a country's ability to generate, adopt and diffuse knowledge. This is an indication of overall **potential** of knowledge development in a given country. Methodologically, KI is the simple average of the normalised performance scores of a country or region on the key variables in three Knowledge Economy pillars – education and human resources, the innovation system and information and communication technology (KEI and KI Indexes (KAM 2012)).

In turn, the Knowledge Economy Index (KEI) takes into account whether the environment is conducive for knowledge to be used effectively for economic development. It is an aggregate index that represents the overall level of development of a country or region towards Knowledge Economy.

According to the research of the World Bank conducted in 2012, Knowledge Economy Index (KEI) ranking in the top five included Sweden (9.43), Finland (9.33), Denmark (9.16) the Netherlands (9.11) and Norway (9.11) out of 146 countries. Ukraine was in 56 place in the overall ranking of index 5.73 and ranked first among the countries with income below average (Table 1).

Table 1. Ranking of countries by Knowledge Economy Index (KAM-2012)

Rank	Country	Index		Components							
				Economic and institutional regime		Education		Innovation		ICT	
		KEI	KI	Rank	Index	Rank	Index	Rank	Index	Rank	Index
1	Sweden	9,43	9,38	4	9,58	6	8,92	2	9,74	2	9,49
2	Finland	9,33	9,22	2	9,65	11	8,77	3	9,66	6	9,22
3	Denmark	9,16	9,00	3	9,63	15	8,63	5	9,49	13	8,88
4	Netherlands	9,11	9,22	19	8,79	12	8,75	7	9,46	5	9,45
5	Norway	9,11	8,99	8	9,47	3	9,43	17	9,01	17	8,53
6	New Zealand	8,97	8,93	14	9,09	1	9,81	22	8,66	23	8,30
7	Canada	8,92	8,72	7	9,52	16	8,61	10	9,32	24	8,23
8	Germany	8,90	8,83	13	9,10	23	8,20	12	9,11	8	9,17
9	Australia	8,88	8,98	23	8,56	2	9,71	19	8,92	22	8,32
10	Switzerland	8,87	8,95	6	9,54	41	6,90	1	9,86	7	9,20
...
56	Ukraine	5,73	6,33	93	3,95	21	8,26	59	5,76	77	4,96

Source: KAM 2012 (www.worldbank.org/kam)

Analysis of the table suggests that the countries belonging to the group of countries with high gross national income (GNI) per capita rank in the first place, i.e. the High Income group, where GNI per capita amounts to more than \$ 12 000 per year². Thus, it can be argued that there is a relationship between KEI and the level of economic development for each country. It is also confirmed by the founded correlation coefficient between the values of KEI and the value of GDP per capita. The value of 0.773 indicates a significant direct correlation between the selected variables (calculated by the authors). However, it should be noted that this relatively high correlation does not explain the causal relationship between the level of KEI and economic development, since high values of KEI are not always accompanied by a high level of GDP per capita.

To investigate the relation between economic growth and knowledge economy, the dynamics of the rate of change of some components of knowledge economy (Table 2) must be analysed first based on the statistics for the period between 1996 and 2011 for Ukraine, Poland, Germany and Lithuania.

² <http://data.worldbank.org/country>

Table 2. Components of Knowledge Economy

Components of Knowledge Economy	Indicators of knowledge economy components
Innovation System	Patent applications, residents
	Patent applications, non-residents
	Researchers in R&D (per million people)
	Scientific and technical journal articles
	Research and development expenditure (% of GDP)
	GERD in '000 current PPP\$
	High-technology exports (current US\$)
	High-technology exports (% of manufactured exports)
	ICT goods exports (% of total goods exports)
Education and Human Resources	Gross enrolment ratio, ISCED 5 and 6, total
	Number of students in tertiary education per 100,000 inhabitants, total
	Public spending on education, total (% of GDP)
Information and Communication Technology (ICT)	Mobile cellular subscriptions (per 100 people)
	Telephone lines (per 100 people)
	Fixed broadband Internet subscribers (per 100 people)
	Internet users (per 100 people)
	Personal computers (per 100 people)
Economic and institutional regime	Regulatory quality index
	Control of corruption index
	Government Effectiveness index
	Rule of law index
	Index of economic freedom

Source: Compiled by the authors from <http://data.worldbank.org>; <http://info.worldbank.org/governance/wgi/index.aspx#home>; http://stats.uis.unesco.org/unesco/ReportFolders/ReportFolders.aspx?CS_referer=&CS_ChosenLang=en

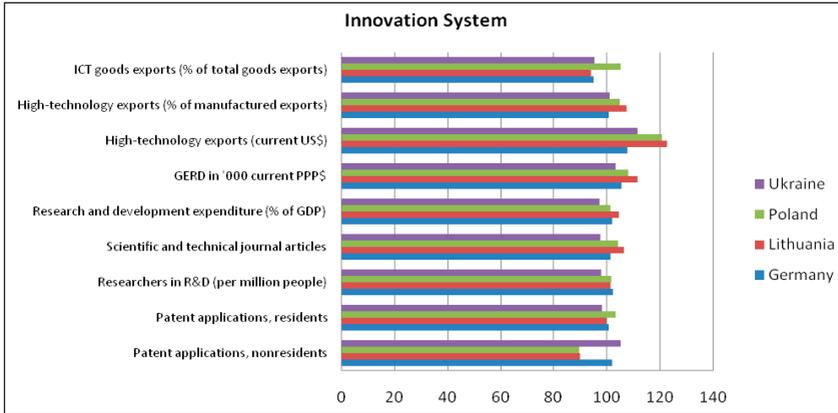
The rate of change (%) and the corresponding average rates for each indicator component of knowledge economy were analysed using the statistics for the period between 1996 and 2011 for Ukraine, Poland, Germany and Lithuania.

Dynamics of average change rate of indicators for the “Innovation System” component is shown in Fig. 1.

Figure 1 shows that among the nine indicators of the “Innovation System” component, Lithuania has the highest average rate of change on five indicators: High-technology exports (current US \$) – 122.51 %, High-technology exports (% of manufactured exports) – 107.23 %, GERD in '000 current PPP \$ - 111.46 %, Research and development expenditure (% of GDP) – 104.29, Scientific and technical journal articles – 106.29 %. Germany has the highest average rate of change in Researchers in R & D (102.22 %), Poland in Patent applications, residents – 103.22 %, export of ICT goods (% of total exports) – 105.05 %. As it can be seen from the graph, Ukraine has a low progress in all indicators of the

“Innovation System” component, with the exception of the indicator “Patent applications, non-residents”, which amounts to 104.98 %.

Figure 1. Dynamics of average change rate for the component “Innovation System”

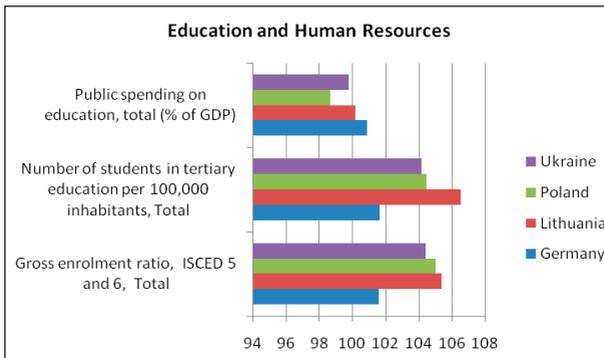


Source: generated by the authors using the data from the World Bank

It should be noted that this analysis shows only the dynamics of changes in those parameters. As for the absolute values of these parameters, Germany has the highest value.

Investigation of dynamics of average rate of change of the “Education and Human Resources” component shows that the indicator “Number of students in tertiary education per 100,000 inhabitants” has the highest growth rate (Fig. 2). The maximum average growth rate is observed in Lithuania (106.55 %). It should also be noted that the rate of change in public spending on education (% of GDP) is almost unchanged, and even during 2010-2011 the costs are reduced.

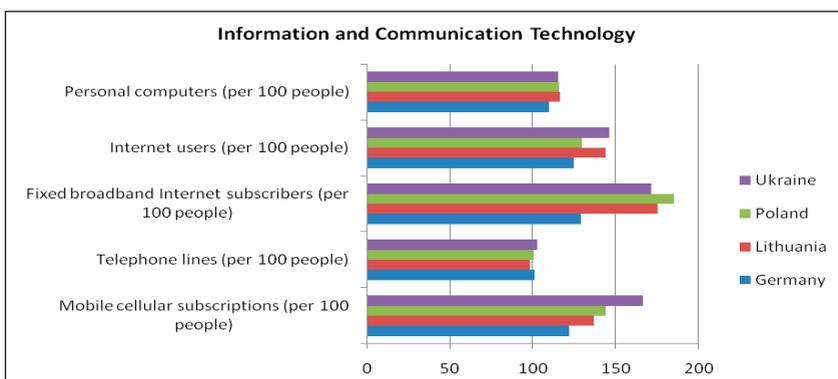
Figure 2. Dynamics of the average change rate for the component “Education and Human Resources”



Source: generated by the authors using the data from the World Bank

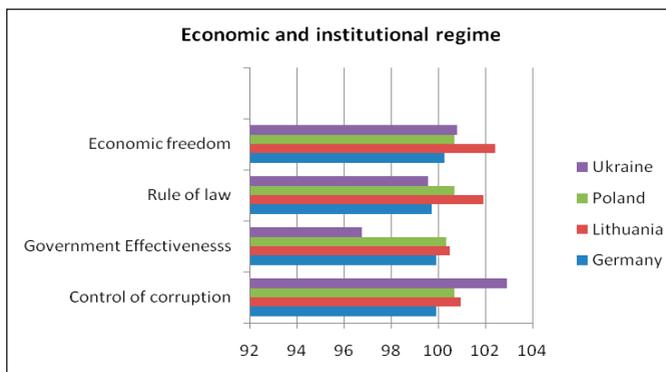
Regarding the analysis of the dynamics of indicators of the “Information and Communication Technology” component, high average rate of change is observed for those parameters. This component has rapid changes due to the formation and development of the information society. In recent years we see the increasing number of people employed in information technology, communications and production of information products and services. Today global information space that provides an effective information interaction of people and their access to global information resources is created. Average rate of change of the “Information and Communication Technology” indicators is shown in Fig. 3.

Figure 3. Dynamics of the average change rate for the component “Information and Communication Technology”



Source: generated by the authors using the data from the World Bank

Figure 4. Dynamics of the average change rate for the component “Economic and institutional regime”



Source: generated by the authors using the data from the World Bank

The analysis of the indicators of the “Economic and institutional regime” component shows that Lithuania has the highest average rate on the “Rule of Law” indicator and the “Economic freedom” indicator with values of 101.92 % and 102.46 % respectively. Poland has the highest average rate on the indicators of “Regulatory quality” and “Government Effectiveness” with values of 100.69 % and 100.36 %, and Ukraine – on the “Control of corruption” indicator» with value of 102.92 % (Fig. 4).

The analysis of the dynamics of knowledge economy components is inexhaustible. As part of this approach, we can qualitatively and quantitatively investigate the contribution of each indicator in the corresponding component of knowledge economy, build a model of interaction and create forecasts, thus creating a system of management of these indicators.

3. The relationship between economic growth and knowledge economy indicators

Economic growth is the increase in the market value of the goods and services produced by an economy over time, the increase in national income or gross national product. Economic growth depends on many factors, including the development of knowledge and science. It is therefore important to know how different factors affect the GDP per capita and therefore choose a specific set of independent variables that can provide a better analysis of this influence.

The analysis is carried out by using NeuralTools Add-In for Microsoft Excel. Neural Networks are capable of learning complex relationships in data. NeuralTools is a Microsoft Excel neural networks add-in, enabling the analysis of data in Excel worksheets and working in the familiar Microsoft Office environment. NeuralTools supports different neural network configurations to give the best possible predictions.

Modelling process using neural network consisted of the following steps:

1. Data collection for the neural network study. For neural network construction, the data from Table 2 are used. The empirical study was based on the data of 32 European countries (the number of observations was 424).
Given that the indicators have their own units of measurement at different scales, each of the indicators was normalised.
2. The choice of network topology. GRNN (Generalised Regression Neural Networks), and MLF (Multi-Layer Feedforward Networks) can be used for the prediction of numerical values. Neural Tools allow selecting the best network based on Root Mean Square Error parameter. 6 models were built: GRNN and 5 MLF with the number of hidden neurons from 2 to 6.
3. Learning Network. As a criterion of process end, two parameters were selected: the training time is 2 hours and the number of trials is 1000000.
4. Model Adequacy Check. To check the adequacy of the neural network, tests were made based on test samples. Test results showed that neural networks could be used for prediction, as they provided the accepted level of error.

- Table (3) shows the results of analysis of the factors affecting the GDP per capita. The table values are presented in percentage terms, and the sum of all values is equal to 100%. The higher the value, the greater the impact of a variable.

Table 3. The analysis of impacts of knowledge economy components on GDP per capita

Components of Knowledge Economy	Value
Innovation System	29,0488%
Education and Human Resources	15,1556%
Information and Communication Technology (ICT)	38,0784%
Economic and institutional regime	17,7171%

Source: defined by the authors using neural network report

The following conclusions can be drawn from Table analysis. One of the advantages of using neural networks is the ability to analyse the impact of independent factors on the predicted value (GDP per capita (current US\$)). Analysing the results of constructed neural networks, the component of Information and Communication Technology has the largest impact on predicted GDP per capita (current US\$) (38.0784 %), and the Innovation System is in the second place (29,0488 %).

At the same time, to analyse the closeness between the components of knowledge economy and GDP per capita, correlation coefficients were calculated (Fig. 5).

Figure 5. Correlation coefficients

Variable	Correlations (Ranking sta)				
	Information and Communication Technology	Innovation System	Economic and institutional regime	Education and Human Resources	GDP per capita (current US\$)
Information and Communication Technology	1,000000	0,689121	0,731307	0,292718	0,766555
Innovation System	0,689121	1,000000	0,509793	0,100408	0,587689
Economic and institutional regime	0,731307	0,509793	1,000000	0,224220	0,551075
Education and Human Resources	0,292718	0,100408	0,224220	1,000000	0,188757
GDP per capita (current US\$)	0,766555	0,587689	0,551075	0,188757	1,000000

Source: calculated by the authors

The table of correlation coefficients shows a close relationship between GDP per capita and the component of Information and Communication Technology (0.766555).

Thus, at present, the development of the information and communication knowledge sector is of particular relevance in the study of the knowledge economy components and according to its relationship with economic growth.

Conclusions

Knowledge economy is a long-term driver of economic growth. Information and knowledge are a direct productive force, one of the most important factors of modern

society development. A branch of knowledge and information production now becomes more and more important as it determines prosperity and competitiveness. This means that leadership in today's world depends on the level of knowledge-based industries, information and communication infrastructure, level of training of scientific bases for developing knowledge-based economy and new technologies. Thus, the concept of knowledge economy should form the theoretical basis for economic growth.

Therefore, one of the possible strategies of Ukrainian economy development is to put knowledge at the service of social and economic development through the creation of favourable conditions for the generation of ideas and innovations for the use by different entities.

Modernisation of Ukrainian economy should be a long-term strategic priority for socio-economic development of the country, only in this case Ukraine can rely on full participation in the global economy.

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EKONOMINIO AUGIMO TYRIMAS ŽINIŲ EKONOMIKOS SĄLYGOMIS

Santrauka. Straipsnyje analizuojamas ekonomikos augimo pobūdis žinių ekonomikos kontekste. Yra parinkti rodikliai, kurie gali apibūdinti atskirus žinių ekonomikos komponentus. Žinių ekonomikos sudedamųjų dalių dinamikos analizė atlikta, pasirėmus Ukrainos, Lenkijos, Vokietijos ir Lietuvos statistiniais duomenimis. Neuroninis tinklas buvo sudarytas panaudojant žinių ekonomikos rodiklius remiantis laiko eilučių duomenimis 1996–2011 metais. Sukurtas neuroninis tinklas gali būti naudojama kuriant ekonomikos augimo prognozavimo modelius

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