

**I. Oleksiv<sup>1</sup>, D. Mirzoieva<sup>2</sup>**

Lviv Polytechnic National University

<sup>1,2</sup> Department of International Business and Management

<sup>1</sup>0000-0001-7387-6933, <sup>2</sup>0000-0002-7349-2857

## **ECONOMIC COMPLEXITY AND KNOWLEDGE ECONOMY: DIFFUSION OF THE KNOWLEDGE AS A FACTOR FOR ECONOMIC GROWTH**

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The purpose of the paper is the establishment of relationships between economic complexity and knowledge economy. The main method is correlation analysis, namely a pairwise correlation test. Another characteristic of the chosen approach is the employment of Economic Complexity Index (ECI) and Knowledge Economy Index (KEI). The main finding is a strong and statistically significant correlation between the economic complexity index and the knowledge economy. Additionally, strong and statistically significant results were confirmed between economic complexity, institutions, and innovative system. Aspects of economic complexity were defined. Also, a new direction is the implementation of the pairwise correlation tests for Economic Complexity Index, Knowledge-Economy Index and pillars of the latter.

The obtained results can be used for the formation of economic strategies, planning and regulation.

**Keywords:** economic complexity, knowledge economy, knowledge flows, knowledge diffusion.

### **Problem statement**

In the modern globalized world, knowledge is a key source of advantage at the international market. Therefore, a knowledge economy is considered as a new type of national economy, which is based on the creation, accumulation, and use of knowledge to sustain economic growth and improvement of well-being [1]. At the same time, a concept and theory of economic complexity have been receiving comprehensive research as it considers productive knowledge as a source for economic growth and development. This interception of two approaches allows to understand the existence of links between knowledge and economic complexity.

### **Analysis of recent research and publications**

The theory of economic complexity started to develop rapidly in recent years. C. A. Hidalgo and R. Hausmann set the principles of economic complexity theory in their introduction of the method of reflections [2]. The main idea of the theory is an evaluation of the complexity of a country on the basis of knowledge in the goods it produces [3]. The higher complexity of the exported goods means higher knowledge intensiveness, innovativeness and level of development of a national economy. Moreover, according to Hidalgo's research, economic complexity can be employed as a predictor of economic growth

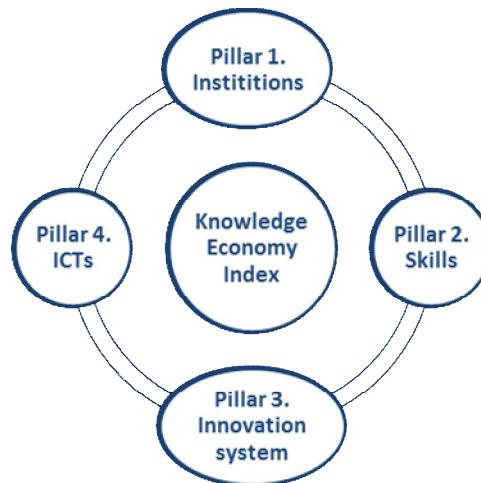
[4]. Mishra S., Tewari I. and Toosi S. noted that economic complexity is «an important metric to measure nations' inherent capabilities» [5]. Balland et al. consider economic complexity as “a powerful paradigm to understand key societal issues and challenges of our time” [6]. Additionally, economic complexity is suggested to be used as a new measure of international competitiveness [7]. Moreover, Pugliese and Tacchella researched the problems of innovations and competitiveness for Slovakia by implementing economic complexity approach and found electronics as the source of growth [8]. Also, a positive impact of economic complexity was found for knowledge diffusion through bilateral trade [9]. The researchers developed different methods to estimate economic complexity. Specifically, for now, the most widespread method to evaluate is Economic Complexity Index [3]. The index permits to evaluation country's economic complexity by applying standard rules and is a universal method to conduct a comparative analysis of a country's competitiveness. At the same time, there is no direct evidence confirming the link between economic complexity and the knowledge economy. We are going to analyze them by applying the main results of economic complexity research.

### **Formulation of hypothesis and goal setting**

The main hypothesis of current research is strong and positive links between economic complexity and knowledge economy as a source of strong institutions, high-skilled human capital, innovation system, and information and communication technologies. These factors potentially create an enabling environment for knowledge diffusion and innovative process to introduce and produce new export products. Accordingly, the purpose of this article is estimation the interconnections between levels of economic complexity and knowledge economy of different countries.

### **Research methods**

The most unified measurement for economic complexity is Economic Complexity Index (ECI), introduced by Hidalgo and Hausmann [2]. This measurement is based on relatedness between categories of goods produced by a country and the ubiquity of export products among all exporters. In literature, different measures for the assessment of knowledge exist. Nevertheless, the measure of knowledge economy, Knowledge Economy Index (KEI), captures not only results of knowledge diffusion and implementation but enabling environment and required resources as well. This measurement was developed by European Bank for Reconstruction and Development (EBRD) for OECD countries and 38 countries credited by this organization. KEI consists of four pillars (Fig.1).



*Fig. 1. The four pillars of Knowledge Economy Index*

Source: [10]

To perform the pairwise correlation was decided to use data on ECI and KEI for 2011 and 2018. The dataset includes 41 countries and two years for each, which allowed receiving 82 observations. The pairwise correlation test was employed for several relations:

- to check the existence of a correlation between values of ECI and KEI to identify the association between a highly developed knowledge economy and economic complexity;
- to check the existence of correlations between four pillars of KEI and ECI to identify which pillars have strong correlations with economic complexity.

For each correlation coefficient, statistical significance is provided.

### Main part

The first step of research included the building of a list of researched countries. To optimize the list was decided to group countries by levels of economic complexity and levels of the knowledge economy. For instance, the economic complexity ranking includes five groups: high, upper-middle, middle, lower-middle and low. The levels of development of the knowledge economy are divided into OECD countries, advanced, intermediate and early stages. The results of grouping and list of countries are presented in Tab.1.

*Table 1*  
**List of countries grouped by values of ECI and groups by knowledge economy levels**

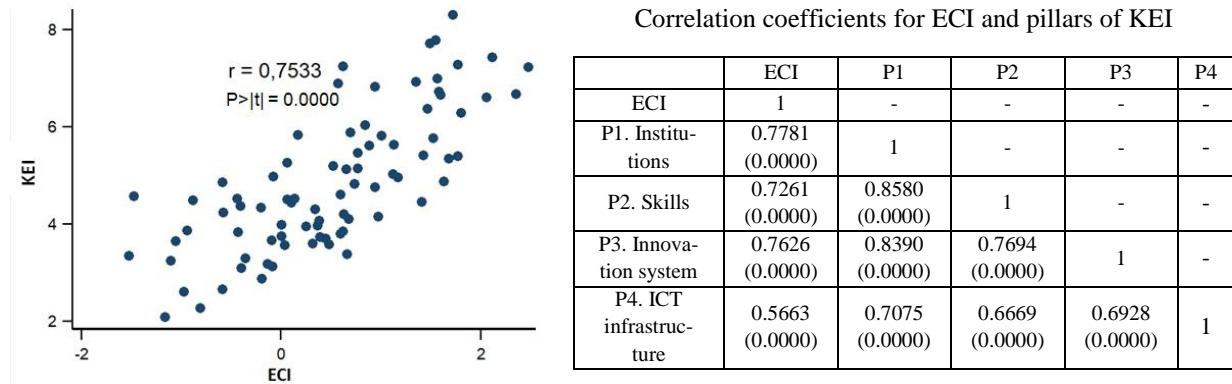
Groups by Knowledge Economy Index \ Levels by Economic Complexity Index	High	Upper-middle	Middle	Lower-middle	Low
OECD	Czech Republic Germany France Japan Sweden United Kingdom United States	Canada	–	–	–
Advanced	Hungary Slovakia	Croatia Estonia Latvia Lithuania Poland	Cyprus	–	–
Intermediate	Slovenia	Bulgaria Romania Serbia	Georgia Greece Jordania North Macedonia Moldova	Albania Armenia Kazakhstan Mongolia	Azerbaijan
Early	–	Bosnia and Herzegovina Turkey	Egypt Kyrgyz Republic Lebanon Tunisia Ukraine	Morocco Tajikistan Turkmenistan Uzbekistan	–

Source: elaborated by authors on the basis of [3, 10].

The presented table itself already demonstrates that OECD countries and countries of the advanced knowledge economy have high levels of economic complexity. However, there are some differences, for instance, Canada and Slovenia.

As a result, the tendency is revealed: generally, countries with greater values of Economic Complexity Index are associated with higher values of Knowledge Economy Index. Such a possible relationship confirms the main assumptions: knowledge economics develops along with economic

complexity. Accordingly, to EBRD methodology development of ICTs is a way to improve the knowledge economy in countries in the early stage of its development. Therefore as a next step was decided to check the existence of correlation and its statistical significance between ECI, KEI and its four pillars. Results are presented in Fig. 2.

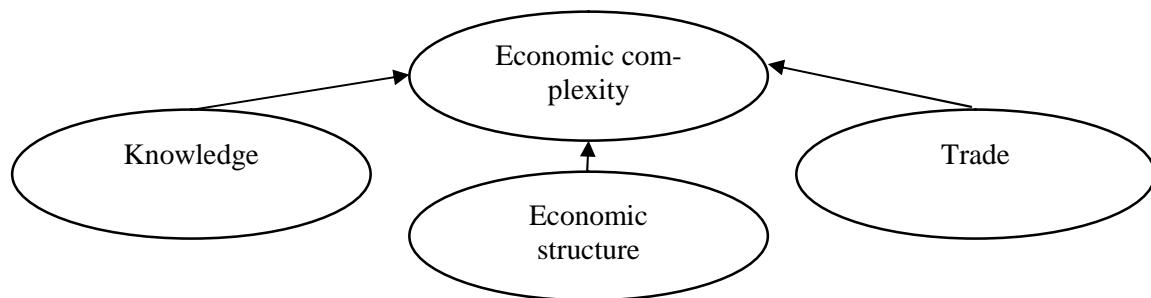


*Fig. 2. Correlation analysis results*

Source: calculated by authors.

The correlation between ECI and KEI is 75 % and is statistically significant at the level of 99 %. Such results support previous findings. All correlation coefficients between ECI and pillars of KEI are statistically significant at the level of 99 %. Moreover, three pillars demonstrated correlation strength higher than 70 %, and only ICT infrastructure demonstrated 56,6%. Institutions demonstrated the most significant correlation coefficient for innovations and innovation systems. Therefore for countries is a crucial task to create and sustain enabling environment for knowledge creation and diffusion. Also is worth mentioning the importance of trade regulation, as not all knowledge-intensive goods can be exported with the same ease.

To make a conclusion was decided to analyze the relationships between dimensions of knowledge economy pillars and economic complexity. To understand how pillars of the knowledge economy affect economic complexity its theoretical aspects were defined (Fig. 3).



*Fig. 3. Theoretical aspects of economic complexity*

Source: elaborated by authors on the basis of [2,4].

The knowledge aspect includes all activities related to knowledge diffusion, innovations and technologies. Economic structure presents economic activities in national economy. Trade aspect consists of trade terms, export strategy and other indicators of international trade.

The next step is an investigation of how pillars of the knowledge economy affect the main aspects of economic complexity:

1. Institutions for innovations:

1.1. Economic openness: affects trade aspect. The terms of trade and tariff rates impact complexity in the directions of highly technological export. For example, low tariffs for raw materials encourage producers to export not complex goods. Favorable conditions for foreign investors result in entry of new companies and new production, which allows to produce of new goods and to improve economic complexity. Another aspect of economic openness is international migration. Highly skilled workers can improve knowledge diffusion and innovative process.

1.2. Business environment: affects economic structure. The ease of doing business, high corruption tolerance, and significant role of law encourage the development and growth of businesses. As a result, producers can start new economic activities, modernize their equipment, and conduct research and development.

1.3. Governance: affects all aspects of economic complexity. The overall stability, government effectiveness, and relevant regulation also facilitate business activity as state policies are consistent and understandable.

2. Skills: affects economic complexity through knowledge aspect and economic structure.

2.1. General skills: the quality school education creates further knowledge diffusion.

2.2. Specialized skills: the firm formal training, quality of higher education, and activities of researchers and technicians are directly involved in knowledge creation and diffusion. As a result of the development of specialized skills, the high innovation and research activities it is possible to optimize production processes and introduce new products.

3. Innovation system: affects economic complexity through knowledge aspect and economic structure.

3.1. Inputs: is mainly focused on research and development activities conducted by firms and government support, which creates conditions for knowledge diffusion. Additionally, strong protection of intellectual property rights is favorable for innovative activities.

3.2. Outputs: includes innovative results, intellectual property receipts, and scientific results that can be implemented directly for the elaboration of new products.

3.3. Linkages: the strong linkages between universities and companies enhance productive knowledge diffusion and help to shape an optimized labour market and as the result, economic structure. Other characteristics of this dimension include the adoption of new technologies and value chain breadth, which directly indicate the level of development of economic complexity.

4. ICT infrastructure: affects economic complexity through all aspects.

4.1. ICT availability: helps to create new channels of communication and electronic commerce. Also, ICT availability can increase the number of new economic activities.

4.2. ICT sophistication: improves knowledge diffusion channels and allows economic activities and international trade transformation.

However, ICTs evaluation in the EBRD methodology does not include exports of ICTs or share of digital services in the export of services, which can be a reason for the low correlation between ICTs pillar and economic complexity.

## **Conclusions**

As the results of the conducted research, the existence of a strong correlation between economic complexity and knowledge complexity was confirmed in the dataset of 41 countries. Additionally was found that institutions and innovation structure show a strong relationship with economic complexity. A significant result is the statistical significance of the received results. Finally, theoretical aspects of economic complexity were distinguished and explained how knowledge economy pillars affect economic complexity through these aspects.

### **Prospects for further research**

The specific measures for assessment of ICTs, the more detailed analysis of statistical relationships for different groups of countries, and elaboration of strategies for the development of economic complexity by improvement of institutions and innovation systems can be research objects in future research.

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**О. І. Олексів<sup>1</sup>, Д. Р. Мірзоєва<sup>2</sup>**

Національний університет «Львівська політехніка»

<sup>1,2</sup>Кафедра менеджменту і міжнародного підприємництва

### **ЕКОНОМІЧНА СКЛАДНІСТЬ ТА ЕКОНОМІКА ЗНАНЬ: ДИФУЗІЯ ЗНАНЬ ЯК ФАКТОР ЕКОНОМІЧНОГО ЗРОСТАННЯ**

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Метою роботи було встановлення взаємозв'язків між економічною складністю та економікою знань. Також в статті було запропоновано новий напрямок досліджень, а саме пошук кореляційних коефіцієнтів між індексом економічної складності, індексом економіки знань та основними компонентами останнього. В роботі застосований кореляційний аналіз, а саме парний кореляційний тест. Іншою характеристикою обраного підходу є використання індексу економічної складності (ECI) та індексу економіки знань (KEI). Основним висновком є наявність сильної та статистично значущої кореляції між індексом економічної складності та економікою знань. Крім того, були підтвержені сильні та статистично значущі зв'язки між економічною складністю, інституціями та інноваційною системою. В результаті застосування методу визначено аспекти економічної складності. Внаслідок проведеного дослідження встановлено наявність сильної кореляції між економічною складністю та складністю знань. Така залежність була встановлена в результаті аналізування даних сорока однієї країни. Країни були розбиті на п'ять груп за рівнем економічної складності, а саме: висока, верхня-середня, середня, нижня-середня та низька. Крім того, було виявлено, що інститути та інноваційна структура мають сильний зв'язок із економічною складністю. Істотним результатом дослідження є статистична значущість отриманих результатів. Теоретичні аспекти еко-

номічної складності були виділені та пояснені, як аспекти економіки знань впливають на економічну складність через ці аспекти. В результаті дослідження була виявлено тенденція: країни з більшими значеннями Індексу економічної складності асоціюються з вищими значеннями Індексу економіки знань. Такий можливий зв'язок підтверджує основні припущення: економіка знань розвивається разом з економічною складністю. Відповідно, для методології ЄБРР розробка ICT є способом удосконалення економіки знань у країнах на ранній стадії її розвитку. Отримані результати можуть бути використані для формування економічних стратегій, планування та регулювання.

**Ключові слова:** економічна складність, економіка знань, потоки знань, дифузія знань.