"Economy of knowledge and transfer of innovations: Ukraine's progress through the lens of European development trends"

AUTHORS	Olena Shkarupa Dmytro Vlasenko Halyna Makedon Svitlana Bilan Desislava Serafimova

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Olena Shkarupa (Ukraine), **Dmytro Vlasenko** (Ukraine), **Halyna Makedon** (Ukraine), **Svitlana Bilan** (Ukraine), **Desislava Serafimova** (Bulgaria)

ECONOMY OF KNOWLEDGE AND TRANSFER OF INNOVATIONS: UKRAINE'S PROGRESS THROUGH THE LENS OF EUROPEAN DEVELOPMENT TRENDS

Abstract

In advanced economies, the acceleration of scientific and technological progress, the introduction of innovations are connected with the opportunities for developing the knowledge economy, commercialization of technologies and innovation transfer networks. The current stage of scientific and technical progress takes place in conditions of dynamic global competition and at the same time requires cooperation and collaboration. This paper aims to determine the dependence of economic development on indicators characterizing the potential of a country's knowledge economy and transfer of innovations. The study focuses on finding ways to assess the impact of the potential of the country's scientific and educational activities on innovative development using the characteristics of the "business-education-science" system in the field of innovation transfer. The methodological research tools are the abstract-logical method and correlation-regression analysis, which allowed establishing relevant links between the indicators of the development of education, science and the economy in the context of the knowledge economy and the transfer of innovations for Ukraine and European countries in the period 2016–2021. It was found that in many countries of the "new" Europe (Bulgaria, Greece, Lithuania, Latvia, Estonia, Slovakia, Slovenia, Cyprus, Malta, Portugal), as well as in Ukraine, the trend of independence of GDP growth from indicators of the development of science and education is maintained. At the same time, the countries of "old" Europe maintain their innovative progress at a high level, investing in science-intensive activities, infrastructure and the R&D sector. The results can be used to improve the efficiency of innovation transfer in Ukraine, for which the paper provides relevant recommendations.

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Olena Shkarupa, Doctor of Economics, Professor, National University of Life and Environmental Sciences of Ukraine, Ukraine. (Corresponding author)

Dmytro Vlasenko, Ph.D., Associate Professor, National University of Life and Environmental Sciences of Ukraine, Ukraine.

Halyna Makedon, Ph.D., Associate Professor, National University of Life and Environmental Sciences of Ukraine.

Svitlana Bilan, Ph.D., Associate Professor, Department of International Economic Relations, Education and Research Institute for Business, Economics, and Management, Sumy State University, Ukraine.

Desislava Serafimova, Ph.D., Associate Professor, Department of Management and Administration, University of Economics, Bulgaria.

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INTRODUCTION

Despite some progress in achieving Goals 7 and 8 of the UN Millennium Declaration, which are a reference point for transformations for sustainable development at the global level (more than 500 international agreements and conventions have been developed, standards for the management of innovative projects, environmental audit schemes, etc. have been developed), economic mechanisms for creating an effective transfer of innovations, their scaling, sharing the best practices of their implementation, and stimulating the diffusion of innovations remain imperfect.

The link between sustainable development, national security and the quality of cooperation between the scientific and educational community and business is enshrined in the UN Millennium Declaration. The most common form of innovation scaling through the cooper-

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ation in the field of education, science and business are technopolises and science (technology) parks, most of which are concentrated in the USA (140 parks), Finland (17 parks), China (53 national parks and more than 50 provincial parks); but to date, they do not fully ensure the transmission and quality of transfer mechanisms. In particular, in Ukraine, their functioning and effectiveness is restrained due to unresolved issues of their institutional and resource support (UN, 2021; Ilchuk, 2018).

Ukraine ranks 60th out of 141 in terms of the level of innovative activity and 47th out of 160 in terms of achieving the Sustainable Development Goals, which is due to the lack of effective mechanisms for cooperation between business and the academic environment, the diffusion of ideas into the real sector of the economy, and institutional support for innovation transfer networks (The World Bank, 2021). This inhibits the processes of qualitative transformation of the country's economy, creates obstacles for the scientific and educational community to perform its constructive functions. The gap between the innovative development of Ukraine and the developed countries continues to increase, which necessitates additional research.

1. LITERATURE REVIEW

The main vector of economic development should be the movement towards the knowledge economy, which effectively uses innovations for the development of the economy with most industries in this case becoming "science-intensive". It is well-known that in the developed countries, approximately 70% of GDP growth is ensured due to new knowledge. It is created to a greater extent due to the development of business, which in European countries operates in various industries and spheres of production, including traditional ones, however, the main part of risk capital investments is related to high technologies.

Information technologies, computerized systems and high production technologies are the basic systems of the knowledge economy (Tarasov et al., 2020), which is formed in the conditions of the most effective mechanism for the formation of cooperation between business, educational and scientific institutions. This contributes to the creation of a fundamentally new landscape for the generalization and consolidation of innovation transfer models, in the process of which the emergent property of each component of the "business-education-science" system is manifested.

With imperfect management in the field of competition between the educational, scientific and business environment for breakthrough ideas and developments, natural barriers to the transfer of innovations are created, which strengthen the existing "innovation gaps" at the macro level, which slows down the transition to the knowledge economy. An effective economy involves the creation of new ideas, their introduction into production not only for the purpose of making a profit, but also to promote progressive social development.

Many works are devoted to the problems of developing innovative entrepreneurship and scientific potential as components of the knowledge economy (Mrykhina, 2018; Pysarenko et al., 2018; Corsi et al., 2020; Wulung et al., 2018; Arenas & González, 2018; Pujotomo et al., 2020; Piroozi, 2017; Li & Tan, 2020; Akhter et al., 2022; van Deventer et al., 2022; Petrushenko et al., 2021, and others). Scientists from the developed countries, in particular, from the USA, Great Britain, Germany, Italy, Spain, the Netherlands, etc., have the most significant scientific results on the researched issues. However, it has been established that currently there is no single scientific vision that would make it possible to scientifically justify the potential of the "business-education-science" system in their mutual goal-setting for the common goal – ensuring economic security and creating an innovative landscape in Europe. The analysis of publications of the last period shows that they are more focused on the external effects and challenges of the innovation transfer process and do not take into account the international aspects of convergent internally variable mechanisms between countries (Yun & Liu, 2019; Lytras et al., 2019; Aden, 2021). Other works explore certain issues in the field of innovation transfer, in particular, the commercialization of academic research (Jones & de Zubielqui, 2017) or technology transfer only between business and the business environment (Brehmer et al., 2018; Sousa et al., 2021; Plastun et al., 2019; Alekseieva et al., 2021; Sang, 2022). Ávila et al. (2017) identified barriers to innovation and the work (Corsi et al., 2020; Soloviov, 2022) analyzed individual and cultural components of innovation transfer. Cooperative interaction is considered as a new area in the literature (Bouncken et al., 2018), which is a relatively new trend of scientific research. The authors believe that such an approach has economic and political advantages that makes it possible to benefit from the exchange within the framework of international economic relations.

At the same time, it is believed that globalization increases the unevenness of the socio-economic development of national economies. This regularity manifests itself at all levels, in particular, in the process of formation of the knowledge economy. Hence the importance and priority of developing a national strategy for the development of the knowledge economy and the effective transfer of innovations. More than 10 years ago, Meyer (2006) noted the main problems of Ukraine's innovation model and the consequences of an ill-conceived innovation policy, pointed out the need to accelerate the implementation of measures related to the scientific and technical development of the economy, strengthening its scientific potential. However, in the conditions of the political crisis, issues related to the formation and development of the knowledge economy in Ukraine have not been sufficiently covered in the literature. In Ukraine, the knowledge economy has an opportunity to adapt to new market conditions and the international situation. These possibilities are due primarily to the high educational potential of Ukraine's population, the possibilities of the innovation process and sufficiently developed material and technical base of the national innovation system. At the same time, there are objective factors restraining the advancement of Ukraine in the knowledge economy, namely, insufficiently perfect legislative framework for innovative activity, low efficiency of state management and regulation of the economy and underdevelopment of venture business. The legislative framework of Ukraine regulates innovative activities regarding the determination of scientific, technological and innovative priorities, financial support, rules for the operation of technoparks and technology transfer, but they are partially effective.

Currently, the gap between innovative development of Ukraine and developed countries continues to increase. According to the data (The World Bank, 2021), Ukraine has practically not changed its position in the ranking of the global innovation index over the past five years. Experts indicated the limited access to finance as the most problematic factor for implementing innovations and conducting business in Ukraine these years (NDIIV, 2021). The authors note that the indicators for the development of the innovation field testify to the negative influence of the management sphere on the development of business and attraction of investments. At the same time, the decline in the quality of provision of educational services and the level of scientific development, the insignificant use of innovative developments at enterprises, the insecurity of intellectual property rights, the migration of qualified personnel to the developed countries make progress in Ukraine impossible (NDIIV, 2021). Therefore, it is necessary not only to develop science-intensive production, but also to demonstrate increased activity in the preservation and multiplication of scientific and technical, innovative and human potentials.

This conclusion is corroborated by the information provided in the Global Innovation Index Monitoring Report published by the World Intellectual Property Organization (WIPO, 2021). The Global Innovation Index (GII) is calculated by the analytical center of the Lausanne Business School INSEAD, Switzerland. The calculation of the index is due to the separation of groups of indicators: the results of innovations (Innovation Output) – contains the results of creative activity, the development of technologies and economic knowledge, and the index "innovation resources" (Innovation Input Index). This sub-index consists of five sub-indices: Institutions; Human potential; ICT and general infrastructure; Development of markets; Business development.

Based on the analysis of literary sources, it was established that this index belongs to the most well-known and widely accepted in the world theory and practice of measurement and comparative analysis of innovative development of countries.

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Ukraine maintains its position, namely 49th place in the world and 32nd place among 39 European countries in 2021. Statistically significant data for the ranking of Ukraine in the GII 2021 are positioned between 43rd and 53rd places. Along with this, in Ukraine, good indicators remain in the field of knowledge and technology (33rd place), and the most difficult situation is in infrastructure (94th place). A very important index – "Human Capital and Research" – after which Ukraine ranks 44th (WIPO, 2021).

According to the 2021 edition of the GII, an interesting situation emerges from the example of Switzerland. This country maintains its leadership positions for the 11th year in a row. Sweden and the United States are also in the lead. The other EU member states in the top ten are the Netherlands (6th), Finland (7th), Denmark (9th) and Germany (10th). The lowest ranked EU Member States are Romania (48th), Greece (47th), and Croatia (42nd) (WIPO, 2021). Table 1 shows the progress of the GII for Ukraine and the top three economies in Europe.

Switzerland also leads in terms of innovation efficiency (1st in the world). This means that the mechanisms for converting innovation costs into innovation outcomes in Switzerland are among the most efficient economies in the world in converting innovation costs into innovation outcomes (WIPO, 2021). The analysis of the literature shows that new ideas and innovations are of decisive importance for ensuring economic growth in the future as evidenced by the efforts of the developed countries to maintain the level of investment in innovative activities. According to the data (WIPO, 2021), the volume of investment in innovation reached a historical maximum during this period. Thus, the growth of state budget investments continued in the countries with the highest expenditures on science. In 2020, companies that are the leaders in spending on science and research increased their total spending in this area by approximately 10% (according to the survey, 60% of science-intensive companies). 2020 saw a 5,8% increase in the number of venture capital deals, which exceeded the average annual growth rate of the last 10 years (WIPO, 2021). In 2020, the number of scientific publications in the world increased by 7,6%. The indicators of 2021 suggest that venture activity will be even more dynamic this year. In order to strengthen their innovation potential under the conditions of global competition, companies seek to expand cooperation with other enterprises, universities and state scientific organizations practicing the model of open innovation. Finding partners and managing various cooperative relationships become challenges, especially from the point of view of the distribution of intellectual property rights. In recent years, discussions about the role and functions of actors interacting according to the "triple helix" model, which is sometimes also called the "knowledge triangle" (knowledge triangle), have intensified. Within the framework of this approach, special

Table 1. Global innovation index of Ukraine and three European countries in 2016–2021

Source: WIPO (2021, 2022).

Ukraine			
Year	**GII**	**Innovation inputs**	**Innovation outputs**
2021	49	76	37
2020	45	71	37
2019	47	82	36
2018	43	75	35
2017	50	77	40
2016	56	76	40
Europe – Switzerland (Swi), Sweden (Swe), United Kingdom (UK)			
Year	**GII**	**Innovation inputs**	**Innovation outputs**
2021	1 (Swi), 2 (Swe), 4 (UK)	4 (Swi), 2 (Swe), 7 (UK)	1 (Swi), 2 (Swe), 6 (UK)
2020	1 (Swi), 2 (Swe), 4 (UK)	2 (Swi), 3 (Swe), 6 (UK)	1 (Swi), 2 (Swe), 3 (UK)
2019	1 (Swi), 2 (Swe), 5 (UK)	2 (Swi), 4 (Swe), 6 (UK)	1 (Swi), 3 (Swe), 4 (UK)
2018	1 (Swi), 3 (Swe), 4 (UK)	2 (Swi), 3 (Swe), 4 (UK)	1 (Swi), 3 (Swe), 6 (UK)
2017	1 (Swi), 2 (Swe), 5 (UK)	3 (Swi), 2 (Swe), 7 (UK)	1 (Swi), 3 (Swe), 6 (UK)
2016	1 (Swi), 2 (Swe), 3 (UK)	6 (Swi), 5 (Swe), 7 (UK)	1 (Swi), 2 (Swe), 4 (UK)

attention is paid to universities and state scientific organizations, their contribution to innovation activity. There is an opinion that the transfer of knowledge and technologies has a positive effect on qualitative and quantitative indicators of scientific productivity. According to numerous observations, scientists who actively participate in this process, for example through patenting, have high authority and in most cases are distinguished by their productivity in performing research and development R&D (Pysarenko et al., 2018; Arenas & González, 2018). The publishing activity of scientists usually increases in carrying out scientific research and developing inventions. The positive impact on publication indicators and citations of scientists is indicated in works (Buenstorf, 2009). In technical sciences, scientists are very active in patenting the obtained results (Meyer, 2006; Fukugawa, 2009; Bogdan & Lomakovych, 2021), and the transfer of knowledge and technologies by universities directly depends on the quality of science.

Continuous relationships between business and universities are a complementary link in innovation activity and are the basis for the idea of the "open innovation" model (Chesbrough, 2006; Weckowska, 2015; Kim et al., 2022; Kim & Jindabot, 2022). Companies performing R&D activities more often interact with universities and state scientific organizations, which contributes to more active investments in innovation processes. At the same time, the connection is most actively visible in the involvement of private research organizations, and with regard to interaction with the state sector of science – this dependence is insignificant (Hryhorash et al., 2022; Govind & Küttim, 2016; Kapustian et al., 2021). An important aspect is also the factor of belonging to the global sector of companies, which, unlike firms focused on the domestic market, maintain strong ties with both private and public scientific organizations (Piątkowski, 2020).

We believe that companies that find it difficult to adapt to changing market conditions and crisis phenomena have increased survival risks (Govender & Hassen-Bootha, 2022; Juhász et al., 2022). OECD documents (OECD, 2013) cover the effect of intersectoral "flow" of knowledge and innovation, which stimulates the search for new forms of innovative activity. Therefore, it can be concluded that the scientific activity of higher educational institutions is one of the important factors in the development of innovative processes and can be taken into account in further calculations. In the context of the investigated issues, it is important to note that an effective focus on the resulting indicators of innovative activity stimulates the transfer of innovations. Innovations are spread through various channels such as mobility of academic staff, scientific publications, new contracts with business, licensing of university inventions. However, recently, the attention of experts in European countries has focused primarily on stimulating the transfer of knowledge and innovation processes through publications, patenting, licensing of inventions and support of academic start-ups. Recently, there has been an increased interest in public-private partnerships, "open" research and "entrepreneurial" channels, including student start-ups and related funding as well as mobility support schemes (Ilchuk, 2018; Kézai & Szombathelyi, 2021). In addition to budgetary support, many universities and state scientific organizations provide startups with their investment schemes with the involvement of their own funds. There are 73 such funds in Europe, including Chalmers Innovation Seed Fund, Gemma Frisius Fonds KU Leuven. Among other things, they provide business and consulting services, provide production facilities in incubators, conduct marketing research and organize professional training.

It is necessary to determine the factors that influence the formation of the scientific and technical, innovative and economic potential of Ukraine. Taking this into account, the purpose of this study is to establish the degree of density of connections between the indicators that form the potential of the knowledge economy for the transfer of innovations in the context of the country's innovative development.

2. METHODS

It is proposed to determine the presence and the degree of closeness of relations between indicators affecting the transfer of innovations in the field of knowledge economy taking into account their

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dynamics for 2016–2021 (Table 1). Models of innovative development of Ukraine and European countries will be built on the basis of the received data. The variance analysis procedure consists in determining the ratio of systematic (intergroup) variance to random (intragroup) variance in the measured data. To analyze the model of innovative cooperation, it is advisable to use this initial value of correlation-regression analysis of SS (Sum of Squares) – the sum of squared deviations. The SS intergroup variability is usually called the error variance. This means that usually when conducting an experiment, it cannot be predicted or explained. The resulting indicator is the gross domestic product (Y) – an indicator that characterizes a country's economic growth in current prices. Four indicators were selected for each country, which, according to the authors' research (Pererva et al., 2012; Corsi et al., 2020), have the greatest impact on GDP, namely, X1 – export of high-tech goods, million US dollars. The export of high-tech products involves the export of goods with a high R&D intensity. Examples of such goods include various rocket and space vehicles, computers, pharmaceuticals, scientific instruments and electrical equipment; X2 – research and development expenditures of countries, billion US dollars. Research and development expenditures are the current and capital expenditures (public and private) for creative activities that are conducted systematically to advance knowledge, including knowledge of humanity, culture, and society, and the use of knowledge for new applications, and include basic research, applied research and experimental developments; X3 – the number of researchers in the R&D sector, per million people. That is, it is the number of specialists engaged in the development and creation of new knowledge, products, processes, methods or systems, and engaged in the management of relevant projects; X4 – the number of articles in scientific and technical journals (pieces) published in the following fields:

Table 2. Mathematical models of GDP dependence of Ukraine and European countries on four groups of factors

Source: Babak (2022).

Country	Model
Austria	Y = –0.0001X1 + 1.3752X2 + 0.0708X3 + 0.0212X4 – 297.028
Belgium	Y = –0.0018X1 + 17.7324X2 – 0.0161X3 + 0.0068X4 + 268.6806
Denmark	Y = –0.1061X1 – 5.4725X2 + 0.2087X3 – 0.03371X4 + 6666.904
Finland	Y = –0.0092X1 + 45.7613X2 – 0.0466X3 – 0.0258X4 + 571.3291
France	Y = –0.0010X1 + 10.2897X2 + 0.3343X3 – 0.0023X4 + 526.3754
Germany	Y = 0.0026X1 + 11.8140X2 + 0.2701X3 + 0.0088X4 – 749.09
Ireland	Y = 0.0061X1 + 103.2214X2 + 0.2698X3 – 0.0967X4 – 1003.84
Luxembourg	Y = 1.3426X1 – 2252.08X2 + 0.1064X3 – 1.4067X4 + 1281.51
Netherlands	Y = 0.0727X1 – 563.978X2 – 1.26X3 – 2.6749X4 + 92503.95
Sweden	Y = 0.2523X1 + 60.0428X2 – 0.6437X3 – 0.1691X4 – 951.689
Greece	Y = 0.0072X1 + 18.4686X2 + 0.0021X3 + 0.0149X4 – 38.0526
Italy	Y = –0.0016X1 + 43.9880X2 – 0.0377X3 + 0.0148X4 – 241.753
Portugal	Y = –0.0248X1 + 34.7453X2 + 0.0302X3 – 0.0055X4 + 122.7192
Spain	Y = 0.0709X1 – 398.577X2 + 1.5438X3 – 0.1813X4 + 11195.71
Bulgaria	Y = 0.0318X1 + 12.3547X2 + 0.0055X3 – 0.0103X4 + 56.5
Croatia	Y = 0.0304X1 + 14.7259X2 + 0.0129X3 + 0.0984X4 – 148.347
Cyprus	Y = 0.0197X1 – 61.3518X2 – 0.00022X3 + 0.0165X4 + 8.7481
Czech Republic	Y = 0.0583X1 – 44.4426X2 + 2.7331X3 + 0.0415X4 – 3418.15
Estonia	Y = –0.001X1 + 0.209X2 + 0.0074X3 – 0.0062X4 + 8.8829
Hungary	Y = –7.0876X1 – 91.8444X2 + 82.1738X3 – 24.2245X4 + 127710.5
Latvia	Y = 0.0104X1 – 46.266X2 + 0.0011X3 + 0.0026X4 + 12.2565
Lithuania	Y = 0.0225X1 – 24.5194X2 – 0.0172X3 – 0.0122X4 + 81.538
Poland	Y = 0.0013X1 + 17.6395X2 + 0.1199X3 + 0.026X4 + 339.8233
Romania	Y = 0.1939X1 – 83.5552X2 – 1.2663X3 + 0.1129X4 + 20.134
Slovakia	Y = –0.0069X1 – 8.7912X2 + 0.0328X3 + 0.0276X4 – 87.9154
Slovenia	Y = 0.0339X1 – 34.0845X2 – 0.006X3 + 0.0179X4 – 34.6471
Malta	Y = –0.0053X1 – 62.0028X2 – 0.0058X3 – 0.0342X4 + 17.5466
Ukraine	Y = –0.6154X1 – 25.9709X2 – 3.6878X3 + 0.4482X4 + 3754.884

physics, biology, chemistry, mathematics, clinical medicine, biomedical research, engineering and technology, Earth science and space sciences. Regression analysis makes it possible to obtain equations for the GDP indicator, taking into account the influence of the specified indicators. For more detailed analysis, a regression analysis of the influence of independent variables on the dependent variable is shown. Table 2 shows mathematical expressions of the model of dependence of the countries' GDP on four groups of factors based on the results of analysis for the countries of "old" and "new" Europe and Ukraine.

3. RESULTS

A comparative analysis of the indicators of Ukraine and European countries shows that in Ukraine there is a significant impact of the studied indicators on GDP. Correlation-regression analysis solves two main tasks: determining, with the help of a regression equation, the analytical form of the relationship between the effective and factor indicators and establishing the level of density of the relationship between them.

Detailed analysis of output data allows analyzing the obtained mathematical expressions of the model of dependence of the countries' GDP on certain factors (Table 3).

Table 3. Results of modeling innovative development in Ukraine and European countries

Country	SS
Countries of "old" Europe	
Austria	1,725.77
Belgium	2,026.57
Denmark	44,746.35
Finland	467.10
France	27,422.62
Germany	110,022.91
Ireland	9,362.65
Luxembourg	63.85
Netherlands	6,567.31
Sweden	416,717.92
Countries of "new" Europe	
Greece	42.50
Italy	12,928.26
Portugal	623.29
Spain	18,031.76
Bulgaria	420.04
Croatia	1,718.82
Cyprus	9.55
Czech Republic	613,913.99
Estonia	23.11
Hungary	60,084,090.07
Latvia	18.61
Lithuania	53.18
Poland	100,287.41
Romania	52,325.08
Slovakia	102.87
Slovenia	42.82
Malta	8.82
Ukraine	
Ukraine	2,467,452.22

4. DISCUSSION

As can be seen from Table 3, Bulgaria, Lithuania, Latvia, Estonia, Slovakia, Slovenia, Cyprus, Malta, Greece and Portugal, and only two countries of "old" Europe (Finland and Luxembourg) have the lowest intragroup variability, which indicates the independence of their GDP from factors such as the export of high-tech goods, research and development costs of countries, the number of researchers in the R&D sector, the number of articles in scientific and technical journals. In all other countries, on the contrary, high intragroup variability, especially in the countries of "old" Europe is observed.

Therefore, the gap between innovative development of Ukraine and developed countries continues to increase. Therefore, it is necessary to be more active in the preservation and multiplication of scientific and technical, innovative and human potentials.

The obtained results correlate with the results of many scientists. According to Tkachova and Pererva (Tkachova et al., 2017; MON, 2021), the main problems of development of the innovation model in Ukraine in the period 2016–2021 were: weak innovation policy and preservation of economic backwardness trends; low interest of the state in carrying out measures to accelerate the scientific and technical development of the country and strengthen its scientific potential. In recent years, economic reforms were aimed at building market institutions, and the development of the

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scientific sphere was slow. At the same time, in the past period, the developed countries not only actively involved Ukrainian specialists, but also carefully developed their scientific sector as the main strategic direction of their national economy (Dolgova & Enes, 2019). License agreements are used for the development of a system of commercialization of innovations among companies, universities and organizations. In Great Britain, they are formed using the Lambert Toolkit software package, model agreements on cooperation in the field of R&D are provided in Germany, in Denmark – standard Schlüter agreements, and model agreements on the DESCA consortium in the projects of the Seventh Framework Program of the EU. This instrument was developed in response to requests from businesses that have difficulty entering into licensing contracts with public research organizations (OECD, 2013). Therefore, one of the areas of development of innovation transfer is a toolkit for knowledge exchange between the university and industrial sectors by drawing up contracts and documents regulating intellectual property rights in the future. A promising area of further research is to study the tools of cooperation between business and science for the most effective results.

CONCLUSIONS

This study is devoted to establish the impact of the knowledge economy for innovative development on the economic progress of Europe. Attention is paid to the transfer of innovations as a tool for managing innovative business activities and networks in innovative activities at the international level. The study focuses on the importance of cooperation between the educational and scientific and business sectors for the effectiveness of the process of creating new technologies and their commercialization, as well as the issues of investing in the resource component of the knowledge economy. Therefore, the study focuses on four factors and their impact on GDP: the export of high-tech goods, the impact on the development of the country, the number of achievements in the R&D sector, the quantity of articles in scientific and technical journals.

Thus, while this study does not demonstrate new methods for estimating the impact of innovation, it helps to focus on the factors of innovation development that capture the performance of academia using statistically significant variances. It has been concluded that the countries of old Europe are carefully building a policy of innovation, investing financial resources in science-intensive areas and educational and scientific environment for the qualitative development of human resources. This allows to maintain a leading position within the geographic affiliation. According to calculations, it was revealed that the economies of 10 countries of new Europe (Bulgaria, Lithuania, Latvia, Estonia, Slovakia, Slovenia, Cyprus, Malta, Greece, Portugal) and two countries of old Europe (Finland and Luxembourg) do not depend on the selected factors, which is due to the structure of their industrial sphere. The Ukrainian economy, on the contrary, is dependent on the number of scientists, the publication of articles and the export of high-tech products and the financing of science, which indicates the need to improve the system for the transfer of innovations and create potential to develop innovative capacity.

Further research is related to the development of methodological approaches to assessing the probability of overcoming the gaps in the development of the economy in comparison with the developed countries of Europe.

AUTHOR CONTRIBUTIONS

Conceptualization: Olena Shkarupa, Svitlana Bilan, Desislava Serafimova.
Data curation: Dmytro Vlasenko, Halyna Makedon.
Formal analysis: Dmytro Vlasenko, Halyna Makedon.
Funding acquisition: Olena Shkarupa.
Investigation: Olena Shkarupa, Dmytro Vlasenko, Desislava Serafimova.

Methodology: Dmytro Vlasenko.
Project administration: Olena Shkarupa.
Resources: Dmytro Vlasenko, Halyna Makedon.
Software: Dmytro Vlasenko, Svitlana Bilan.
Supervision: Olena Shkarupa, Svitlana Bilan.
Validation: Dmytro Vlasenko, Desislava Serafimova.
Visualization: Halyna Makedon.
Writing – original draft: Olena Shkarupa, Dmytro Vlasenko, Halyna Makedon, Svitlana Bilan, Desislava Serafimova.

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APPENDIX A

Table A1. Export of highly technological goods, million US dollars (X1)

Country	2016	2017	2018	2019	2020	2021
Countries of "old" Europe						
Austria	21,648.68	18,086.95	17,339.82	17,027.61	16,687.50	16,687.50,
Belgium	45,574.60	40,736.62	40,255.16	34,397.96	36,817.02	40,830.36
Denmark	10,641.15	10,096.89	10,056.85	8,937.32	9,587.88	9,583.53
Finland	5,102.70	4,250.98	3,966.66	4,405.11	4,515.41	–
France	121,375.78	110,206.32	109,316.53	109,359.05	117,814.41	–
Germany	216,297.04	199,797.31	206,133.81	195,752.36	210,082.31	207,031.30
Ireland	25,865.02	30,632.32	37,990.08	34,827.02	36,493.79	–
Luxembourg	679.50	702.20	811.59	786.64	858.27	–
Netherlands	91,097.05	69,866.17	71,151.46	78,192.85	85,690.57	85,690.57
Sweden	21,452.94	19,016.80	19,144.56	17,434.04	17,441.83	17,474.42
Countries of "new" Europe						
Greece	1,337.15	1,330.54	1,415.26	1,384.00	1,754.80	1,778.21
Italy	33,222.99	30,511.57	31,317.93	32,232.28	32,581.03	34,308.17
Portugal	2,315.73	2,096.41	2,457.33	2,816.24	2,978.22	3,474.26
Spain	16,348.27	15,107.97	15,160.60	17,094.35	16,982.24	15,690.57
Bulgaria	1,154.76	1,186.00	1,366.74	1,684.92	2,012.78	–
Croatia	915.59	915.71	1,336.11	923.41	1,011.94	–
Cyprus	68.74	57.43	56.44	57.71	95.71	92.99
Czech Republic	26,920.80	24,815.45	24,842.64	29,543.51	36,128.84	37,493.79
Estonia	2,708.97	2,053.27	2,106.43	1,844.02	2,065.40	1,863.46
Hungary	15,686.91	14,668.17	15,922.19	16,903.99	18,065.92	18,467.45
Latvia	1,329.49	1,291.46	1,203.46	1,413.24	1,881.86	1,428.75
Lithuania	2,093.09	1,920.34	1,963.43	2,317.94	2,516.32	–
Poland	17,075.51	16,877.96	17,382.61	19,261.85	22,236.77	20,354.18
Romania	4,473.33	4,437.96	5,254.49	5,558.65	6,637.14	6,994.47
Slovakia	8,401.13	7,461.13	7,484.80	8,812.92	8,971.24	8,971.24,
Slovenia	1,622.66	1,556.41	1,673.79	1,755.38	2,089.39	2,089.39,
Malta	858.23	635.09	592.22	655.82	762.25	758.63
Ukraine	2 222.44	1 626.37	1 245.92	1 267.15	1 247.56	1 089.39

APPENDIX B

Table B1. Expenditures on research and development, billion US dollars (X2)

Country	2016	2017	2018	2019	2020	2021
Countries of "old" Europe						
Austria	10.26	10.50	11.18	11.29	12.23	12.23
Belgium	9.63	10.25	11.01	12.04	12.96	12.96
Denmark	57.65	62.11	65.34	66.34	68.73	68.73
Finland	6.56	6.11	5.96	6.23	6.47	6.47
France	49.01	49.90	49.60	50.77	51.94	51.94
Germany	84.02	88.18	91.52	98.65	103.34	103.34
Ireland	2.96	3.10	3.18	3.09	3.73	3.73
Luxembourg	0.63	0.67	0.71	0.74	0.74	0.74
Netherlands	13.30	13.66	14.17	14.62	16.72	16.72
Sweden	125.37	138.89	144.37	157.25	161.27	161.27
Countries of "new" Europe						
Greece	1.48	1.70	1.75	2.04	2.18	2.18
Italy	21.81	22.18	23.23	23.96	24.73	24.73
Portugal	2.23	2.23	2.39	2.61	2.80	2.80
Spain	12.80	13.15	13.25	14.06	14.91	14.91
Bulgaria	0.66	0.86	0.74	0.77	0.84	0.84
Croatia	2.58	2.85	3.02	3.15	3.71	3.71
Cyprus	0.09	0.09	0.10	0.11	0.12	0.12
Czech Republic	84.98	88.70	80.10	90.35	102.74	102.74
Estonia	0.29	0.31	0.27	0.31	0.37	0.37
Hungary	441.37	473.08	430.76	524.28	661.26	661.26
Latvia	0.16	0.15	0.11	0.14	0.18	0.18
Lithuania	0.38	0.39	0.33	0.38	0.43	0.43
Poland	16.17	18.00	17.87	20.49	25.66	25.66
Romania	2.54	3.49	3.67	4.29	4.86	4.86
Slovakia	0.67	0.93	0.64	0.74	0.74	0.74
Slovenia	0.89	0.85	0.81	0.80	0.89	0.89
Malta	0.06	0.07	0.06	0.07	0.07	0.07
Ukraine	10.31	12.13	11.45	13.43	16.73	16.72

APPENDIX C

Table C1. Researchers in the R&D sector, per million (X3)

Ukraine	2016	2017	2018	2019	2020	2021
Countries of "old" Europe						
Austria	4,947.88	5,019.44	5,224.35	5,387.93	5,733.08	5,733.08
Belgium	4,528.92	4,711.05	4,780.52	4,729.55	5,023.26	5,023.26
Denmark	7,310.66	7,528.26	7,846.66	7,924.95	8,065.89	8,065.89
Finland	7,009.29	6,844.55	6,531.48	6,721.83	6,861.11	6,861.11
France	4,233.64	4,307.49	4,414.70	4,561.11	4,715.32	4,715.32
Germany	4,320.70	4,743.79	4,861.75	5,076.52	5,211.87	5,211.87
Ireland	5,304.48	5,270.66	5,178.20	5,401.04	5,243.13	5,243.13
Luxembourg	4,741.07	4,480.00	4,667.99	4,960.21	4,941.70	4,941.70
Netherlands	4,512.60	4,673.08	4,776.84	4,887.22	5,604.54	5,604.54
Sweden	6,875.99	6,834.03	7,154.53	7,383.42	7,536.48	7,536.48
Countries of "new" Europe						
Greece	2,791.87	3,255.99	2,769.90	3,311.45	3,482.72	3,482.72
Italy	1,956.36	2,077.883	2,204.08	2,313.66	2,306.77	2,306.77
Portugal	3,662.38	3,729.77	4,004.58	4,367.73	4,537.53	4,537.53
Spain	2,613.10	2,623.35	2,715.47	2,855.75	3,000.89	3,000.89
Bulgaria	1,821.92	1,977.29	2,237.29	2,125.18	2,342.87	2,342.87
Croatia	1,437.43	1,504.18	1,850.50	1,868.34	1,921.13	1,921.13
Cyprus	1,064.93	1,009.05	1,050.54	1,196.43	1,255.85	1,255.85
Czech Republic	3,402.83	3,592.07	3,516.17	3,682.03	3,862.67	3,862.67
Estonia	3,284.26	3,183.24	3,295.08	3,542.55	3,755.33	3,755.33
Hungary	2,673.43	2,589.10	2,645.76	2,921.53	3,237.70	3,237.70
Latvia	1,854.33	1,808.60	1,596.54	1,784.64	1,792.10	1,792.10
Lithuania	3,054.02	2,785.59	2,950.28	3,071.96	3,190.70	3,190.70
Poland	2,064.05	2,171.58	2,320.79	3,019.12	3,106.12	3,106.12
Romania	903.83	876.23	911.59	891.32	882.44	882.44
Slovakia	2,715.55	2,650.21	2,253.26	2,416.22	2,995.96	2,995.96
Slovenia	4,147.06	3,814.22	3,914.26	4,479.40	4,854.57	4,854.57
Malta	1,831.72	1,891.32	2,054.59	2,130.46	1,946.51	1,946.51
Ukraine	1,023.93	1,006.00	1,037.24	994.08	988.08	980/

APPENDIX D

Table D1. Articles in scientific and technical journals, pieces (X4)

Country	2016	2017	2018	2019	2020	2021
Countries of "old" Europe						
Austria	12,660.94	12,911.21	12,792.84	12,850.61	12,362.28	9,362.28
Belgium	17,143.34	16,724.04	16,763.94	16,278.27	15,688.13	7,688.13
Denmark	14,145.01	14,214.95	14,160.25	14,345.19	13,978.80	9,978.80
Finland	11,314.67	10,942.46	11,106.38	10,768.81	10,598.94	5,598.94
France	73,299.07	71,925.79	71,028.47	70,100.94	66,352.18	61,352.18
Germany	108,473.69	106,452.92	108,295.59	107,803.17	104,396.12	90,396.12
Ireland	7,194.18	6,847.04	7,044.16	7,108.63	7,174.11	5,174.11
Luxembourg	877.68	816.12	857.78	814.16	869.10	769.10
Netherlands	31,878.57	31,141.82	31,014.65	31,048.39	30,457.33	21,457.33
Sweden	21,116.43	20,858.16	20,860.65	20,768.71	20,420.56	20,420.56
Countries of "new" Europe						
Greece	11,664.94	11,237.15	11,156.77	10,986.92	10,906.99	8,906.99
Italy	69,720.32	70,519.39	70,534.27	71,485.25	71,240.28	68,240.28
Portugal	14,569.91	14,691.23	14,348.02	14,391.44	14,294.56	10,294.56
Spain	56,559.76	55,147.04	55,514.33	55,432.15	54,536.59	34,536.59
Bulgaria	2,676.19	2,558.33	2,557.01	2,808.03	3,311.27	3,311.27
Croatia	4,014.91	4,050.72	3,966.92	4,227.47	4,276.90	4,276.90
Cyprus	915.53	935.15	1,059.28	1,193.38	1,245.42	1,245.42
Czech Republic	15,432.41	16,700.33	16,604.51	16,782.25	15,576.60	15,576.60
Estonia	1,690.56	1,578.23	1,555.17	1,559.00	1,414.72	1,414.72
Hungary	6,728.01	6,533.46	6,473.35	6,645.69	6,700.92	6,700.92
Latvia	1,171.05	1,474.02	1,390.79	1,602.91	1,417.73	1,417.73
Lithuania	2,492.17	2,464.44	2,306.22	2,404.65	2,267.30	2,267.30
Poland	31,773.31	33,116.44	34,838.68	34,675.67	35,662.64	35,662.64
Romania	10,073.39	10,917.79	10,511.40	11,039.56	10,345.01	10,345.01
Slovakia	5,007.44	5,062.13	5,492.66	5,787.12	5,321.60	5,321.60
Slovenia	3,501.80	3,557.71	3,357.55	3,448.68	3,206.15	3,206.15
Malta	286.42	314.53	333.94	395.95	422.02	422.02
Ukraine	7,237.53	7,272.89	7,853.62	8,977.67	10,379.89	-

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APPENDIX E

Table E1. GDP in current prices, billion (Y)

Country	2016	2017	2018	2019	2020	2021
Countries of "old" Europe						
Austria	333.15	344.27	357.30	370.30	385.71	398.68
Belgium	403.00	416.70	430.23	445.96	459.53	473.09
Denmark	1,981.16	2,036.36	2,107.81	2,175.11	2,245.95	2,321.49
Finland	206.90	211.39	217.52	225.84	233.62	240.08
France	2,149.77	2,198.43	2,234.13	2,297.24	2,360.69	2,425.71
Germany	2,927.43	3,030.07	3,134.10	3,244.99	3,344.37	3,435.21
Ireland	194.82	262.83	271.68	297.13	324.04	347.22
Luxembourg	49.82	52.07	54.87	56.81	60.05	63.52
Netherlands	671.56	690.01	708.34	738.15	774.04	812.05
Sweden	3,992.73	4,260.47	4,415.03	4,625.09	4,828.31	5,020.80
Greece	178.66	177.26	176.49	180.22	184.71	187.46
Italy	1,627.41	1,655.36	1,695.79	1,736.59	1,766.17	1,787.66
Portugal	173.05	179.71	186.49	195.95	204.30	212.32
Spain	1,032.16	1,077.59	1,113.84	1,161.88	1,202.19	1,245.33
Countries of "new" Europe						
Bulgaria	83.86	89.33	95.09	102.31	109.69	118.67
Croatia	331.34	339.70	351.17	366.43	382.97	400.10
Cyprus	17.41	17.83	18.87	20.04	21.14	21.94
Czech Republic	4,313.79	4,595.78	4,767.99	5,047.27	5,323.56	5,652.55
Estonia	20.18	20.78	21.69	23.78	26.04	28.04
Hungary	32,694.21	34,785.20	35,896.33	38,835.22	42,661.81	46,786.71
Latvia	23.65	24.43	25.07	26.80	29.06	30.48
Lithuania	36.54	37.32	38.89	42.27	45.26	48.43
Poland	1,720.43	1,800.24	1,861.15	1,989.35	2,120.48	2,273.56
Romania	668.59	712.59	765.14	857.90	952.40	1,059.80
Slovakia	76.26	79.76	81.04	84.52	89.61	94.171242
Slovenia	37.63	38.85	40.37	42.99	45.75	48.01
Malta	8.51	9.63	10.34	11.28	12.37	13.21
Ukraine	1,586.92	1,988.54	2,385.37	2,983.88	3,560.60	3,974.56