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ASSESSMENT OF TECHNOLOGICAL COMPETITIVENESS OF UKRAINE IN TERMS OF ASSOCIATION WITH THE EU[7]

Research background: The paper accounts for the problem of assessing the factors of the formation of Ukraine's technological competitiveness in the face of new challenges for the state in the process of developing relations with the EU.
Purpose of the article: The aim of the report is to assess the level of technological competitiveness of the Ukrainian economy and determine the most important factors for its further development in the conditions of association with the EU.
Methods: The article presents the scheme of research of technological competitiveness of Ukraine on the basis of qualitative and economic-statistical analysis, analysis of comparative advantages, cluster and correlation-regression analysis.
Findings & Value added: The analysis of world rankings has shown that the technological competitiveness of Ukraine determines comparative factor advantages in coverage of higher education, availability of scientific staff, and quality of research institutions, but low state support, lack of stability, and problems in institutional development hamper the country's innovative potential. The identification of competitive advantages in trade in high-tech products demonstrates that Ukraine remains an importer of high-tech products; relatively small comparative competitive advantages among the high-tech products of Ukraine has only products of the

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aerospace industry. Cluster analysis showed that Ukraine is in the same cluster as Poland. Bulgaria and Romania, which have not yet fully consistent with the level of technological competitiveness of EU leaders; among the strengths of Ukraine are the development of human resources and labour effect. The correlation analysis between the components of the Global Innovation Index and the factors of increasing Ukraine's competitiveness indicates a moderate link between the development of clusters, the ratio of expenditures on R&D to GDP, and the export of ICT services. In order to increase the level of technological competitiveness of Ukraine: to increase both foreign investments and state financing; improvement of regulatory acts, reduction of corruption, institutional improvement; support of technologies through regional cluster programs or "smart specialisation"; integration into the European Research Area.
Keywords: technological competitiveness; Global Innovation Index; high-tech products; comparative advantages; EU-27 and Ukraine
JEL: C15; F13; F17; O14; O24; O52; O57

Introduction

Presently, in a highly globalised and competitive world, technological change and innovation are the basis of the long-term economic growth of any successful country. As a consequence, the development of economic policy-based countries, based on the development of the scientific, technological, and innovation environment, will contribute to their sustainable economic growth and global competitiveness. At the same time, in the conditions of competition's intensification in foreign and domestic markets for the leading countries of the world, the problem of advanced production technologies' introduction of the 21st-century new industrial revolution is substantially aggravated.

In a highly globalised and competitive world, the basis for a country's long-term economic growth is technological change and innovation. At the same time, the core of technological change and innovation is scientific development. In this context, countries should formulate economic policies to develop a science, technology, and innovation environment in society and the economy that will promote sustained economic growth and global competitiveness (Sener et al., 2011).

Technological readiness is a key element in the growth of each national economy. It is impossible to imagine any aspect of human activity without technological tools. In addition, technology plays a significant role in shaping lifestyles, work, and communication in modern societies. Given this important role in social life and business, the results achieved in technological readiness largely determine the quality of life of citizens and the attractiveness of the economy of a given country. Consequently, the level of competitiveness in terms of technological readiness largely determines the overall competitiveness of a national economy in the global world. These are the main reasons why technological readiness requires special treatment in the formulation of a country's strategic development and why it should be monitored and improved in every national economy that advocates an open development model (Radivojevic et al., 2018).

Thus, competitiveness now is the ability to manage change and adapt to it through innovation. Achieving and maintaining competitiveness requires a constant increase in productivity and constant adaptation to changes in the economic environment (European Investment Bank, 2016).

When change is the only constant, an economy that can attract new ideas, methods, or products faster than others will have an advantage. That is why the use of technological opportunities and innovations can accelerate the growth and development of any economy (The Global Competitiveness Report, 2018).

The economic growth and the national well-being of the country are also determined by the adequate functioning of the banking system (Radukanov, 2014).

According to the European Commission definition, technological competitiveness is the ability of a national economy to generate long-term economic growth, productivity, and well-being, through technological and innovative development. Such development requires an environment for innovation and has the following elements: a high level of education; investment in research and development; and a developed innovative infrastructure, including high-quality research institutions capable of generating knowledge and supporting new technologies; extensive cooperation in scientific and technological development between universities and industry; protection of intellectual property rights, high levels of competition and access to venture capital and finance (Priede, Pereira, 2013).

In this regard, it is essential to assess the risks associated with capital markets. Economic actors are affected by many factors (at the macro and micro levels) with different intensities. This requires companies to be careful about the rapidly changing market environment, which invariably reflects on competitiveness (Radukanov, 2017).

The importance of traditional competitive advantages has diminished considerably in the twenty-first century, and it is only through participation in technological competition in the world market that the competitiveness of national economies is now substantially enhanced. According to Holroyd, supporting scientific and technological innovation in the long term constitutes the main source of competitive advantage (Holroyd, 2007). In most cases, the technological competitiveness of an economy is described by researchers in the context of the impact of a technological factor on the dynamics of foreign trade, innovative competitiveness or innovative support for industrial modernisation (Fedulova, 2008).

Research is gradually reflecting technological competitiveness in the measurement of the domestic development potential of a country's economy. According to K. Momaya, technological competitiveness is the ability to develop, transfer, absorb, produce or commercialise technologies to maintain competitiveness (Momaya, 2001). J. Fagerberg linked technological competitiveness with innovation potential (Fagerberg, 1988). This is also the position of M. Cassidy, D. O'Brien, who, by technological competitiveness, understand the innovative and adaptive potential of the economy (Cassidy, 2007). J. Howells defines a country's scientific and technological competitiveness as a country's ability to create and retain competitive advantages in the generation, diffusion and application of new knowledge through efficient use, building and modernising its scientific and technological capacity in the context of globalisation (Howells, Michie, 1998).

In our view, an approach to analysing the competitiveness of the economy in terms of technological capabilities suggests that competitive differences among countries arise because of differences in their technological capabilities, that is, their ability to absorb, adapt, and efficiently use technology for development, efficiency and productivity.

By 2030, world-renowned institutions and international industry associations are predicted to be able to launch a revolution in industrial production only by introducing, first and foremost, high-tech industries. The wave of the new industrial revolution will drive the rise of new digital industrial technologies known as Industry 4.0, based on industries such as nanomaterials, 3D printing, genetic engineering, molecular biotechnology, cloud computing, multidimensional modelling, the Internet of Things, and artificial intelligence (OECD, 2015; UNIDO, 2014).

Exports of high-tech products are the main indicator measuring technological competitiveness, i.e., the commercialisation of research and development and innovation in international markets. It is the development, exploitation, and commercialisation of new technologies that are vital to a country's competitiveness in the modern economy. High-tech products are a key driver of economic growth, productivity, and welfare, and tend to be a source of high value-added and well-paid employment (European Innovation Scoreboard, 2018).

This revolution is connected with the problem of levelling and improving the EU's economic performance. The dynamics of Europe's future development will depend on the quality of its scientific and technological innovations. In this context, EU Member States should develop economic policies to create a science, technology, and innovation environment that will promote sustained economic growth and global competitiveness. Considering the rather ambiguous state of development of Ukraine's high-tech sphere, the problem of assessing factors of formation of technological competitiveness of Ukraine in the face of new challenges for the state in the process of development of relations with the EU.

The aim of this study is to assess the level of technological competitiveness of the Ukrainian economy and determine the most important factors for its further development in the conditions of the new industrial revolution and association with the EU.

Literature Review

The impact of technological changes and industrial revolutions on the country's international competitiveness is the subject of study by a wide range of foreign economists and analysts. In addition, many well-known scientists offer their own methods for assessing the country's technological competitiveness depending on the influence of various factors of the macro-environment, as well as the direct impact of export volumes and structure on competitiveness.

In their works, Jonson et al. (2010) show that Western European nations, along with the USA and Japan, have been recognised as the most competitive economies in the world. Eastern European countries are generally considered to be lagging behind. They are examining the accuracy of these descriptions and the prospects for change in the coming decade. Georgia Tech 'High Tech Indicators' (HTI) contributes to the National Science Foundation (NSF) Science & Engineering Indicators. They cover 33 highly developed and rapidly industrialising countries. Our model of technological competitiveness contains four components: National Orientation, Socioeconomic Infrastructure, Technological Infrastructure, and Productive Capacity that promote 'Technological Standing'. They present indicator values, derived from survey and statistical panel data, for 13 European nations (plus the USA as a benchmark), for 1993-2005 and draw inferences about future high tech competitiveness. We are witnessing limited technological progress in the Eastern European States. The outlook for Europe is somewhat uncertain, given the sharp increase in competition from Asia.

Porter et al. (2014) showed that the Georgia Institute of Technology, with the support of the National Science Foundation, had completed a decade of developing national high-tech competitiveness indicators. This paper reports on the standing, emphasis, and rate of change of high tech competitiveness for 28 nations. Results show strong standing for the '4 Asian tigers', comparable to many Western European countries. Their five '6 Asian Cubs' are experiencing rapid growth in high-tech production and export opportunities; the four tigers are no longer growing fast. Patterns are presented and discussed as well for 'the Big 3' (Japan, USA, Germany), three non-European developed economies, two former Eastern Bloc countries, and three Latin American nations. Their group of 180 experts predicts a surge in global high-technology export competition over the next 15 years.

To explain these implications, it is necessary to refer to M. Porter's concept of the competitiveness of nations. "The only meaningful concept of competitiveness at the national level is productivity. (…) A nation's standard of living depends on the capacity of its companies to achieve high levels of productivity— and to increase productivity over time" (Weresa M., 2019).

Porter defines the competitiveness of a location as the productivity that companies located there can achieve. He uses this definition of competitiveness to understand the drivers of sustainable economic prosperity at a given location (Ketels, 2006).

Hans-Erik Edsand, following the logic of post-materialist value theory, the rise in GDP per capita and education levels in developing countries suggests that the relevance for including environmental awareness in a developing country study is steadily rising (Edsand, 2019).

Regarding the first aspect, innovative technological competitiveness of the economy is considered in economic literature, in the first place, from the viewpoint of creation and introduction of modern and advanced technologies (Edsand, 2019; Weresa, 2019; Fedulova, 2008). It is the result of public policy of accumulation and use of intellectual capital and introduction of modern technologies that secure the growth of labour productivity and sustainability of production technological and business processes and increases the level of added value in science-intensive economy sectors. However, the approach does not sufficiently take into account the role of business, innovative infrastructure, domestic developments and social effects of technologies introduction.

At the same time, today, all countries must take into account the influence of the main factors of the new industrial revolution. The most widespread concept today, Industry 4.0, was named in 2011 by German businessmen, politicians, and scientists, who identified it as a way of increasing the competitiveness of the German manufacturing industry through the enhanced integration of "cyber-physics systems" (or CPS) into production processes. In the report, Kagermann et al. (2013) the main points of this concept were formulated, and its further development was described in the works of Ross (2016), Schwab (2016), which emphasise that today advanced production technologies are mainly 3D-printing, cloud technology, Internet things, new materials, robotics, and artificial intelligence.

Thus, we can conclude that Industry 4.0 technologies, combining the factors Smart TEMP (T (technology) – smart technologies, E (environmental) – smart environment, M (manufacturing) – smart production, P (products) – smart products), create new markets and industries, contribute to the growth of labour productivity, the competitiveness of sectors and national economies (Matyushenko, 2016, 2017).

But competitiveness is examined within the framework of industrial development and global challenges (Vasyltsiv et al., 2020; Matyushenko, 2016). It is the capacity of industry to introduce and use advanced technologies for competition and solution of global problems (population decline, poverty, environment, new energy, social security). However, in this case, the emphasis shifts from the development of the national economy to the global social level.

The Fagerberg paper (1996) provides an overview of the literature on technology and competitiveness. First, the concept of a country's international competitiveness and various theoretical approaches to the relationship between trade and growth are discussed. A number of empirical studies on the impact of technology (as evidenced by R&D, patents, etc.) on exports are then examined. As a result, the author summarises the findings and discusses lessons for policy. Moreover, America and Zamora Torres (2014), based on foreign experience, argue that the share of high-tech products delivered to world markets is directly dependent on the development of national innovation infrastructure.

The question of improving the economic performance in the EU countries and finding an effective response to the current global challenges is directly linked to the widespread introduction of these advanced industrial technologies by the new industrial revolution in European countries (Balcerzak, 2015; Barca et al., 2012; Becker et al., 2012; Prokopenko et al., 2018).

Many economists have examined specific aspects of the impact of a country's export capacity on its competitiveness in world markets. Thus, Hausmann and Clinger (2006) used one approach to assess the export potential for competitiveness. Looking at the "commodity space" of world exports, they note that a country's level of competitiveness depends on the food basket it exports. The greater the share of a country's high-tech products in world exports, the more competitive it will be. This position has been confirmed by the analysis of statistics from more than 100 countries. Building on this view, Hidalgo & Hausmann (2009) argues that a country's export potential is influenced by a country's income level (namely, GDP): high-tech goods can be exported by high-income countries. It is clear that this point cannot be unconditionally and unequivocally accepted with regard to individual countries.

Melnyk (2008) argues that the components of export potential include: the potential of internal resources (a function of the technical and technological base, staff qualifications, management methods, finance); the potential of the target foreign market; market access conditions, which include national (trade policy of the country, the system of support for export production) and external conditions (trade regime of the exporting country). Indeed, these factors influence the formation of export potential. However, Melnyk only points to the existence of functional dependence of export potential on these indicators, without its further formalisation. Therefore, it is not possible to practically use the approach.

To forecast exports, Kireiev (2001, pp. 435-436) proposes to use regression equations of supply and demand. Accordingly, the demand for national products of the country is determined on the basis of the sum of weighted by the correction factors of real-world GDP and the export price index. This equation is based on the assumption of the existence of global development cycles. In fact, countries are developing locally: around the "centre countries" of production and export of goods are "satellite countries", which have similar economic indicators because of the close trade links between them.

Bogomazova (2003) also provides a regression model for estimating export potential, describing the country's exports on the basis of three variables: the nominal exchange rate of the hryvnias against the US dollar, foreign direct investment inflows into Ukraine, and industrial and agricultural growth rates. In our opinion, such a model does not fully characterise the possibilities of forecasting Ukraine's exports, because regression models are quite difficult because the economic situation is changing very quickly.

In assessing the impact of regulatory authorities on the foreign trade of high-tech products in Ukraine, scientists note the possibility of using cause-effect relationships between indicators characterising the market's business processes and government regulatory instruments that can be quantified (Sushchenko et al., 2016; Koval et al., 2019).

Thus, each of these methodological approaches to assessing the competitiveness of the country, taking into account the export potential of the economy, has its own unique features, advantages, and analytical components.

In our opinion, the strength of the methodological approach is Jonson et al. (2010), Porter et al. (2014) is the use of four components in the technology competitiveness model – national orientation, socio-economic infrastructure, technological infrastructure, and productive potential, as well as the use of high-tech technology indicators to assess their competitiveness. In addition, the authors influence the export of technology (based on research and development, patents, etc.). At the same time, such research requires the processing of a large amount of statistical information, which is often difficult for ordinary researchers to access. In our view, a qualitative analysis based on comprehensive indicators is useful for a comprehensive and sufficiently simple assessment of a country's technological competitiveness.

Scientists and business analysts such as Kagermann et al. (2013), Ross (2016), Schwab (2016), investigated the influence of the factors of the new industrial revolution on the technological competitiveness of the country. At the same time, they came to the conclusion that today, in the context of insufficient statistics on the impact of specific breakthrough technologies on the country's economic development, the best quality indicators of the country's technological competitiveness remain integral indicators, primarily such as Global Competitiveness Index of World Economic Forum, the Global Innovation Index, IMD World Competitiveness Ranking and others.

Another group of scientists (América, Zamora-Torres, 2014; Balcerzak, 2015; Becker, et al., 2012; Fagerberg, 1996; Hausmann, Klinger, 2006; Hidalgo, Hausmann, 2009; Bogomazova, 2003; Kireiev, 2001; Koval et al., 2019; Melnik, 2008; Sushchenko et al., 2016) investigated the impact of trade in technological goods on economic growth and conducted various assessments of the impact of a country's export potential on its technological competitiveness.

The synthesis and analysis, combination and critical contemplation of the abovementioned approaches provide the grounds to conclude that innovative technological competitiveness is the leading element that forms competitive advantages of economy and is defined by the level of science and technology development, sector of the digital economy, up-to-datedness and efficiency of used technologies, volumes of their penetration into the system of the national economy and economic relations at all levels, availability of financial support and resources provision and efficiency of the use of innovative technological activity's results.

An analysis of the results of these studies showed that indicators such as the ratio of high-tech exports to GDP of a country, the ratio of the number of employees involved in research and development to the employed population of the country, the ratio of research and development expenditure (R&D expenditure) to the country's GDP, relative (comparative) country advantages by product group and other categories are useful for a comprehensive assessment of a country's export potential. These indicators are often used to assess a country's export potential in a comprehensive manner and to identify the comparative advantages of its exports.

In addition, cluster analysis and correlation-regression analysis should be added to the above methodological approaches in order to allow for a comparative analysis of different countries.

Thus, there is the problem of some combination of these methodological approaches in order to establish a comprehensive and relatively simple methodological approach to assessing a country's technological competitiveness (as in the case of Ukraine); taking into account the impact of the new industrial revolution and Ukraine's association with the EU.

Research Methodology

The article proposes a methodical approach to the study of the technological competitiveness of the country, which includes four stages:

I. Qualitative analysis of four international integral indicators, namely:

- the Global Competitiveness Index of World Economic Forum (GCI WEF), including an indicator of technological readiness (9th pillar: Technological readiness) and indicator of innovation (12th pillar: Innovation);
- the IMD World Competitiveness Ranking (IMD WCR), in particular, an indicator of infrastructure;
- the IMD World Digital Competitiveness Ranking (IMD WDCR) to assess the country's ability to develop and implement digital technologies;

- the Global Innovation Index (GII) to study the detailed indicators of innovation activities in the world.

II. For the study of the main comparative advantages of Ukraine's high-tech trade, it is proposed to use the Melnik (2008) methodology and to analyse the following indicators:

the ratio of exports of high-tech goods to the country's GDP:

$$QE_{HQ} = \frac{E_{HQ}}{GDP} \times 100\% \quad (1)$$

the ratio of the number of employees involved in research and development to the employed population of the country:

$$\frac{R\&D\ employees}{\text{employed population of the country}} \times 100\% \quad (2)$$

the ratio of research and development expenditure (R&D expenditure) to the country's GDP:

$$\frac{R\&D\ expenditure}{\text{GDP of the country}} \times 100\% \quad (3)$$

the indicator of the relative or comparative advantage of the country. The country's (i) comparative advantage coefficient (CA) for a given product group or industry (j) is an indication of whether a country has a relative advantage in the exports of a particular product group or whether this advantage is shared by its partners:

$$CA_{ij} = \ln [(Ex_{ij}/Im_{ij}) / (Ex_i/Im_i)] \quad (4)$$

Ex_{ij}, Im_{ij} – export and import of j-goods of the i-country;

Ex_i, Im_i –export and import of the i-country.

III. Positioning the country in a European competitive environment through *cluster analysis*.

IV. Modeling the relationship between indices and factors of technological competitiveness based on *correlation and regression analysis*.

The correlation analysis is used to determine and study the relationship between the indicators studied and to establish the relative degree of dependence of the performance indicator on each factor.

The main purpose of multiple regression analysis is to consider the relationships between a dependent variable and several independent variables. It is necessary to analyse the relationship between the resulting variable and the many factors, and then to identify the factors that most influence the outcome. This analysis can predict the value of a finite variable depending on the values of certain factors.

The forecast linear equation that estimates the multiple regression model that will be used (5):

$$Y = a + b_1 \times X_1 + b_2 \times X_2 + b_3 \times X_3 + \ldots + b_n \times X_n; \quad (5)$$

Y is the dependent variable, what is being predicted or explained;

X_1; X_2; X_3;X_n are the independent variables, that are explaining the variance in Y;

'a' is the constant or value of function with zero value of all factors;

b_1;b_2; b_3; b_n are the regression coefficients.

R_2 will be used to describe the precision of the process model. If the value exceeds 0.7, the model is considered reliable.

We will choose Ukraine and the 27 EU countries as a model for the study, because we are interested in how Ukraine's technological competitiveness has changed since the signing of the association agreement with the EU.

We will choose 2011-2019 (2020 at the time of the article's submission) as the research period, as 2011 (according to the world's leading experts) was the beginning of a period of economic recovery in the leading economies after the global financial crisis of 2008-2009. It was also in 2011 that they first began to speak of a new industrial revolution, the main factors of which were having a growing impact on the technological competitiveness of the world's leading economies, particularly those of the European Union, and associated countries.

The result of the research is the identification of the main ways to increase the level of technological competitiveness of Ukraine.

Results

The results of the comparative analysis of the four indicators of Ukraine's competitiveness, namely the GCI WEF (including Technological readiness and innovation), IMD WCR, IMD WDC Rand GII, are presented in Table 1to Table 6 (The Global Competitiveness Reports (2011-2019), IMD World Competitiveness Ranking (2020), IMD World Digital Competitiveness Ranking (2017-2020), The Global Innovation Index (2011-2020)).

The analysis of the world rankings has shown that Ukraine's technological competitiveness is determined by comparative factor advantages in the coverage of higher education, the availability of scientific personnel and the quality of research institutions, but low state support, lack of stability and problems in institutional development hamper the country's innovative potential. Indicators that determine the technological competitiveness of Ukraine demonstrate the low position of the country. So, in 2019-2020 Ukraine ranks 85th out of 140 countries in the GCI WEF, 55th out of 63 countries in the IMD WCR, 58th of 63 countries in the IMD WDCR, 45th out of 141 countries in the GII.

The evaluation of comparative advantages and indicators of export efficiency of the main industries of high-tech products of Ukraine was conducted using the methodological approach of Melnik (2008, pp. 241-271) based on formulas 1-4. The results of calculations of the comparative advantages calculations are shown in Table 7 and Figure 1 (United Nations Commodity Trade (2011-2019), World Bank Open Data (2011-2019)).

It was found that Ukraine remains predominantly an importer in the world market of high technology products, because its foreign trade in high-tech products is characterised by a low share of these products in total exports of the country and a significant trade deficit. The insignificant presence of Ukraine in the world markets of high-tech products is due to the outdated structure of production, low R&D costs and the decline in innovation activities of domestic enterprises. Despite the difficult financial and economic situation in the country, exports of telecommunications, computer and information services have been found to be increasing annually, and in 2020, exports of ICT services in Ukraine amounted to 5.1 billion in value terms. Forecast data indicates that this sector of services will continue to grow. The analysis of comparative advantages has shown that Ukraine has only relatively small comparative advantages in the markets of foreign countries in such high-tech products, as aircrafts, space crafts and their parts. The average comparative advantage was 2.21, while in other cases it was negative.

Positioning the country in a European competitive environment through cluster analysis on all 10 indicators of the European Innovation Scoreboard (EIS) for the EU-27 and Ukraine (Table 8). The result of clustering is shown in Figure 2, where 7 clusters with a threshold value of 310 were identified and presented in Table 9 (European Innovation Scoreboard (2019), Eurostat (2019)).

According to the EIS, all EU member states are divided into four different groups. Denmark, Finland, Luxembourg, the Netherlands and Sweden are "innovative leaders" with innovation indicators that are significantly higher than the average in the EU. Austria, Belgium, France, Germany, Ireland and Slovenia are "active innovators" that are productivity above or close to the EU average. Indicators of Croatia, Cyprus, Czech Republic, Estonia, Greece, Hungary, Italy, Latvia, Lithuania, Malta, Poland, Portugal, Slovakia and Spain are below the EU-27 average. These countries are "moderate innovators". Bulgaria and Romania are "emerging innovators", which performance is significantly lower than the EU average. By level of innovation development, Ukraine is in the same cluster with Bulgaria, Romania, Poland, and Latvia, which have not yet fully been able to adapt their economies to the level of technological and innovative competitiveness of countries such as Germany, the Netherlands, Finland, Austria. Thus, these countries belong to the cluster of "emerging innovators".

Ukraine is a part of cluster 7 (Figure 3), that is far behind the others. The most problematic indicators are "Attractive research system" and "Innovators". If the average EU figure equals 136.6 and 95.9, then for cluster 7, these indicators will be 33.7 and 18.8, respectively. Some advantages countries of cluster 7 have only in indicators of "Innovation-friendly environment" (141.3) and "Employment impacts" (91.7), reflecting general trends in Ukraine. Thus, the cluster analysis showed that Ukraine is now in a single cluster with countries, such as Bulgaria, Romania, Poland, and Latvia, which have not yet fully been able to adapt their economies to the level of technological and innovative competitiveness of the leading countries.

Among countries in cluster 7, Poland and Latvia have the most innovative development. Their strengths include "Innovation-friendly environment", "Employment impacts", "Firm investments", and "Human resources" indicators (Table 8). In Bulgaria, "Intellectual assets" (at the level of Belgium and France) and "Employment impacts" (the highest level among the cluster, which is equal to the same indicator for countries such as Germany and Denmark) are among the greatest advantages of innovative development. Ukraine is the second-to-last cluster country. Romania has the lowest indicators among the EU-27 countries for the components of the "European Union Innovation Scoreboard" like "Human resources", "Attractive research systems", "Firm investments", "Innovators", "Intellectual assets", "Employment impacts". But the available results show that Ukraine has some strengths in the European competitive environment, such as innovation-friendly environment and labour.

For deeper conclusions, further analysis was made of the state of development of technology competition infrastructure (Figure 4). Compared to other countries in the cluster, Ukraine has the lowest level of infrastructure development in the cluster. Poland and Bulgaria are leading on this indicator.

The development of the tax system is important not only for the creation of a country's business environment, but also for the assessment of its technological competitiveness. For the analysis of the tax system, the development of the total tax rate and contributions as a percentage of profit (Figure 5) for 2016-2020 was analysed. In 2020, the highest tax rate was in Ukraine (45.2%), although during 2016-2018, this rate tended to decrease. In countries such as Latvia, Poland and Bulgaria, the tax rate has not changed much during 2016-2020 and is always at a certain level of 28-40%. Romania has the lowest income tax rate among the countries studied, which was 20% in 2020. Accordingly, it is Romania that has the most attractive tax conditions for technological competitiveness.

Analysis of labour market conditions for Ukraine and Bulgaria, Latvia, Poland and Romania is given by indicators such as "Workers' rights", "Ease of hiring foreign labour", "Internal labour mobility" (Figure 6). According to the Global Competitiveness Index of World Economic Forum, the more the value of the measure, the higher the value of the indicator. So in 2020, Poland had the best employment conditions, including for foreign workers. Employment conditions in Ukraine are at the average level among cluster countries.

Discussion

To assess the degree of influence of factors of innovation development on the indices that determine the global and technological competitiveness of Ukraine, we will use the method of correlation and regression analysis based on the main indicators of the GCI WEF (including Technological readiness and innovation), the IMD WDCR, the GII and our own calculations.

The factors we chose (independent variables X1-X12) can be divided into the following categories, Table 10:

1. Conditions for creating educational and institutional capacity: expenditure on education (X1), the number of graduates in science and technology (X2), quality of research institutions (X3), the ratio of the number of employees involved in research and development to the employed population(X4);
2. Innovation financing: the ratio of R&D expenditure to the country's GDP(X5), FDI inflows (X6);
3. Innovative infrastructure: access to ICT (X7), state of cluster development (X8);

4. The economic effect of innovation: the ratio of exports of high-tech products to industrial exports (X9), the ICT services exports (X10), the number of PCT patents (X11), income from intellectual property use (X12).

As dependent variables (Y1-Y5), the indices that reflect the competitiveness of Ukraine were selected, namely the GCI WEF (Y1) and its main indicators, such as "Technological readiness" (Y2) and "Innovation" (Y3); the GII (Y4) and the IMD WDCR (Y5).

Based on the table of initial data for the indicated indicators in the period 2011-2019, a correlation analysis was carried out, the results of which are presented in Table 11.

The data given in Table 11 show that the GCI WEF of Ukraine has basically a very weak relationship with such factors as the number of graduates in science and technology, expenditure on education, the quality of research institutions, the ratio of R&D expenditures to GDP, and FDI inflows. The GCI WEF is closely related to only one indicator of the state of cluster development (0.594), and has little in common indicators such as ICT access, ICT services exports and education expenditure.

The relationship between technological development and the factors we have chosen is weak or moderate. There is a strong correlation between this index and expenditure on education (-0.729) and income from intellectual property use (-0.730), state of cluster development (0.516), the ratio of R&D expenditure to GDP (-0.624) and access to ICT (-0.371).

The relationship of innovation potential to the factors selected is mostly either strong, very weak or almost non-existent. Thus, indicators such as access to ICT (0.844), income from intellectual property use (-0.909), export of ICT services (0.802), number of PCT patents (0.703) and the ratio of R&D expenditure to GDP have a significant relationship with Ukraine's innovation potential (-0,755).

The correlation between the GII and the factors we have selected shows that the relationship between them is mostly moderate or strong. The three main factors are the ratio of R&D expenditure to GDP (-0.879 – a very close relationship), state of cluster development (-0.727) and the ratio of high-technology exports to industrial exports (-0.743).

The IMD WDCR has the greatest connection with indicators such as FDI inflows (0.802), the number of PCT patents (0.787), and income from intellectual property use (-0.734).

To complete the study, a multiple regression analysis was conducted based on the factors the correlation with which the correlation was strongest.

On the basis of the multiple regression analysis of the modelling and prediction of changes in the values of the main indices that determine the global and technological competitiveness of Ukraine, it has been possible to establish the following:

The coefficient of determination is insignificant ($R^2 = 0,5592$), so the reliability of the model is very low and the results of regression analysis on this factor indicate that there is no relationship between the Global Competitiveness Index and the selected factors. Building a model does not make sense (Table 12, 13).

$Y = 2.5351 + 0.0707 \times X_2$.

The increase in the number of graduates in science and technology by 1% will increase the index of technological development (in the GCI WEF) at 0.0707; R^2 = 0.752202(Table 14, 15).

$Y= 3.1108 + 0.0006 \times X_1 – 0.033 \times X_3$.

Improving the quality of research institutions by 1 point will increase the index of innovation potential (in the GCI WEF) to 0.0006. Increasing the revenues from the use of the intellectual property for $1 million will reduce the index of innovation potential by 0.033; R^2 = 0.893797 (Table 16, 17).

$Y = 50.8041 +0.4271 \times X_2$.

Increasing the level of the cluster development by 1 point will increase the GII by 0.4271; R^2 = 0.924411 (Table 18, 19).

$Y= 51.52405 + 2.106391 \times X_1 – 1.71027 \times X_2+ 1.651747 \times X_3$.

An increase of 1% in FDI inflows would result in an increase of 2,106391 points in the IMD WDCR. An increase of 1% in exports of high-tech products to industrial exports would result in an increase of 1,71027 points in the IMD WDCR, and an increase in the number of PCT patents would result in an increase of 1,651747 points in the IMD WDCR; R^2 = 0,840884 (Table 20, Table 21).

Conclusions

The analysis of world rankings has shown that the technological competitiveness of Ukraine is determined by comparative factor advantages in coverage of higher education, availability of scientific staff and quality of research institutions, but low state support, lack of stability and problems in institutional development hamper the country's innovative potential.

Ukraine remains predominantly an importer in the global market of high-tech products, because its foreign trade in high-tech products is characterised by a low share of these products in total exports of the country and a significant trade deficit. It has only small comparative advantages in the markets of foreign countries in such high-tech products, as aircrafts, space crafts and their parts.

The conducted cluster analysis indicates that Ukraine is now in the same cluster with the countries Bulgaria, Romania, Poland, and Latvia, which have not yet fully adapted their economies to the level of technological and innovative competitiveness of the leaders of the countries. The strengths of Ukraine in the European competitive environment include innovation-friendly environment and labour.

Thus, the modelling and forecasting of the development of the main indices, which determine the global and technological competitiveness of Ukraine, showed and made possible the following author's recommendations:

1) It is required to ensure an increase in the number of such graduates by creating and improving research centres at the universities;

2) It is required to diagnose the operation quality of research institutions, develop strategies for their improvement and to achieve adequate state funding for science. The country needs the development of intellectual property legislation and support for small and medium-sized enterprises, which are the driving force behind the country's innovation activity;
3) It is required to develop a program of innovative industrial clusters, which provide for a system of incentives for participants and related fringe benefits and improve the mechanisms of state financial support of cluster development;
4) Ukraine should improve its investment climate. State support is required for the development of high-tech industries and increase in the volume of those types of production, which revealed comparative advantage. It is necessary to increase the funding of science and development (grants, patents, etc.).

In addition, to increase the level of technological competitiveness of Ukraine, it is also necessary to:

a) increase both foreign investment and state financing by improving the country's investment climate, increasing the availability of credit resources for high-tech enterprises and creating special lending programs;
b) broad reform of governance and basic institutions, reduction of corruption, restoration of trust in the government, a reform of the judicial system, improvement of regulatory acts and other institutional improvements;
c) reforming the state and supporting small and medium enterprises, supporting technologies based on the formation and expansion of regional cluster programs or through "smart specialisation";
d) introduction of technology exchange programs, production experience, integration of Ukraine into the world scientific and technological information space, first of all within the framework of the EU.

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ANNEX

Table 1

Positions of Ukraine on the main components of the Global Competitiveness Index (GCI WEF) 2011-2019

	2011	2012	2013	2014	2015	2016	2017	2018	2019
Rank	82/ 144	73/ 144	84/ 148	76/ 144	79/ 140	85/ 138	81/ 137	83/ 140	85/ 141
Basic requirements	98	79	91	87	101	102	96	98	99
1. Institutions	131	132	137	130	130	129	118	110	104
2. Infrastructure	71	65	68	68	69	75	78	57	57
3. Macroeconomic environment	112	90	107	105	134	128	121	131	133
4. Health and primary education	74	62	62	43	45	54	53	94	101
Efficiency enhancers	74	65	71	67	65	74	70	71	70
5. Higher education and training	51	47	43	40	34	33	35	46	44
6. Goods market efficiency	129	117	124	112	106	108	101	73	57
7. Labor market efficiency	61	62	84	80	56	73	86	66	59
8. Financial market development	116	114	117	107	121	130	120	117	136
9. Technological readiness	82	81	94	85	86	85	81	77	78
10. Market size	38	38	38	38	45	47	47	47	47
Innovation and sophistication factors	93	79	95	92	72	73	77	72	73
11. Business sophistication	103	91	97	99	91	98	90	86	85
12. Innovation	74	71	93	81	54	52	61	58	60

Source: the study based on GCIWEF (2011-2019)

Table 2

Dynamics of the main indicators of technological development of Ukraine (GCI WEF) 2011-2019

	2011	2012	2013	2014	2015	2016	2017	2018	2019
Technological readiness	3.74	3.6	3.28	3.5	3.45	3.58	3.8	3.84	3.9
Availability of latest technologies	4.6	4.8	4.3	4.1	4.3	4.3	4.1	4.2	4.3
Firm-level technology absorption	4.6	4.8	4.3	4.2	4.2	4.4	4.3	4.3	4.4
FDI and technology transfer	3.8	4	3.6	3.7	3.8	3.7	3.5	-	-
Internet users, % pop.	23	30.6	33.7	41.8	43.4	49.3	52.5	53.0	58.9
Fixed-broadband Internet subscriptions /100 pop.	8.1	7	8.1	8.8	8.4	11.8	12	12.6	12.3
Internet bandwidth kb/s/user	2.6	9.8	14.3	52.9	40.7	45.7	79.9	-	-
Mobile-broadband subscriptions /100 pop.	-	4.4	5.5	5.4	7.5	8.1	22.6	41.7	45.2

Source: the study based on GCIWEF (2011-2019)

Table 3

Dynamics of key indicators of Ukraine's innovation potential (GCI WEF) 2011-2019

	2011	2012	2013	2014	2015	2016	2017	2018	2019
Innovation	3.1	3.2	3.0	3.2	3.4	3.4	3.4	3.4	3.5
Capacity for innovation	3.4	3.3	3.2	3.6	4.2	4.4	4.3	4.2	4.3
Quality of scientific research institutions	3.6	3.7	3.6	3.8	4.2	4.2	3.9	3.8	3.9
Company spending on R&D	3	2.7	2.7	3.1	3.4	3.3	3.2	3.3	3.4
University-industry collaboration in R&D	3.6	3.6	3.4	3.5	3.5	3.5	3.4	3.5	3.6
Gov't procurement of advanced technology products	3.1	3.2	3	2.9	3	3.1	3	3.2	3.2
Availability of scientists and engineers	4.3	4.8	4.5	4.3	4.7	4.7	4.7	4.6	4.8
PCT patents applications/million pop.	0.3	2.1	2.9	3.2	3.6	3.9	3.6	3.7	3.9

Source: the study based on GCIWEF (2011-2019)

Table 4

Dynamics of the Competitiveness Index of the Ukrainian economy (IMD WCR) 2011-2020

Years	Rank	Infrastructure		
		Technological	Scientific	Education
2011-2012	57/59	48		
		45	43	33
2012-2013	56/59	51		
		53	42	34
2013-2014	49/59	45		
		51	42	32
2014-2015	49/60	44		
		47	42	24
2015-2016	60/61	48		
		54	41	31
2016-2017	59/61	50		
		58	41	30
2017-2018	60/63	53		
		60	44	45
2018-2019	59/63	53		
		55	48	41
2019-2020	55/63	55		
		56	52	43

Source: the study based onIMDWCR (2011-2020)

Table 5

Positions of Ukraine on the main components of the World Digital Competitiveness Ranking (IMD WDCR) 2014-2020

	2014	2015	2016	2017	2018	2019	2020
Overall performance	50	59	59	60	58	60	58
Knowledge	29	40	44	45	39	40	38
Talent	46	55	58	57	55	57	52
Training & education	4	15	20	26	22	21	19
Scientific concentration	42	39	45	45	40	49	50
Technology	58	60	60	62	61	61	59
Regulatory framework	47	55	55	56	54	54	54
Capital	56	60	60	62	61	62	59
Technological framework	58	60	58	60	57	60	58
Future readiness	58	61	61	61	61	62	61
Adaptive attitudes	58	60	60	58	53	59	56
Business agility	42	58	59	56	53	45	51
IT integration	58	61	60	60	61	61	62

Source: the study based on IMDWDCR (2014-2020)

Table 6

Key Indicators of the Global Innovation Index (GII) for Ukraine 2020

Indicator	Score/ value	Rank
Human capital & research	40.5	39
2.1 Education	56.9	23
2.1.1 Expenditure on education, % GDP	5.4	26
2.1.2 Government funding/pupil, secondary, % GDP/cap	30.3	12
2.1.3 School life expectancy, years	14.9	54
2.2 Tertiary education	43.9	32
2.2.1 Tertiary enrolment, % gross	82.7	14
2.2.2 Graduates in science & engineering, %	25.3	35
2.3 Research & development (R&D)	20.5	44
2.3.1 Researchers, FTE/mn pop.	988.1	52
2.3.2 Gross expenditure on R&D, % GDP	0.5	69
2.3.3 Global R&D companies, top 3, mn US$	39.8	38
2.3.4 QS university ranking, average score top 3	21.2	49
Knowledge & technology outputs	35.1	27
6.1 Knowledge creation	41.6	23
6.1.1 Patents by origin/bn PPP$ GDP	5.4	20
6.1.2 PCT patents by origin/bn PPP$ GDP	0.5	36
6.1.3 Utility models by origin/bn PPP$ GDP	23.0	1
6.1.4 Scientific & technical articles/bn PPP$ GDP	9.5	55
6.2 Knowledge impact	28.7	45
6.2.1 Growth rate of PPP$ GDP/worker, %	2.4	39
6.2.2 New businesses/th pop. 15–64	1.7	61
6.2.3 Computer software spending, % GDP	0.0	19
6.2.4 ISO 9001 quality certificates/bn PPP$ GDP	4.5	58
6.2.5 High- & medium-high-tech manufactures, %	16.8	61
6.3 Knowledge diffusion	35.0	32
6.3.1 Intellectual property receipts, % total trade	0.1	46
6.3.2 High-tech net exports, % total trade	1.9	56
6.3.3 ICT services exports, % total trade	5.4	9
6.3.4 FDI net outflows, % GDP	0.2	96

Source: the study based on GII (2020)

Table 7

The value of the indicator of comparative advantage for Ukraine in main high-tech industries in 2011-2019

	2011	2012	2013	2014	2015	2016	2017	2018	2019
Aircraft and spacecraft	1,94	2,29	2,41	2,22	2,25	1,87	2,18	2,71	2,00
Pharmaceuticals	-2,50	-2,36	-2,27	-2,25	-2,20	-2,11	-2,10	-2,12	-2,50
Office, accounting and computing machinery	-1,71	-1,67	-1,92	-2,44	-2,28	-2,46	-2,55	-2,74	-2,49
Radio, TV and communications equipment	-0,80	-0,55	-0,77	-0,81	-1,16	-1,09	-1,22	-0,65	-1,08
Medical, precision and optical instruments	-1,20	-1,76	-1,57	-1,25	-1,28	-1,55	-1,72	-1,76	-1,78

Source: own calculations based on United Nations Commodity Trade Statistics Database (2011-2019)

Table 8

Source data for the cluster analysis on the main indicators of the European Union Innovation Scoreboard for EU and Ukraine

	Humanr esources	Attractive research systems	Innovation-friendly environment	Finance and support	Firm investments	Innovators	Linkages	Intellectual assets	Employment impacts	Sales impacts
Ukraine	53,40	17,27	169,63	11,30	45,13	20,18	37,55	20,90	86,86	35,15
Slovakia	94,30	56,38	87,32	28,29	82,73	37,25	63,03	39,85	140,54	114,23
Slovenia	127,30	100,95	143,03	36,57	134,66	61,36	116,25	81,94	105,27	67,73
Sweden	216,98	210,95	310,18	141,05	175,53	103,43	154,93	122,64	167,78	89,22
Romania	13,64	32,77	112,94	48,11	10,57	0,00	40,48	23,78	45,19	62,07
Portugal	105,07	135,20	227,24	96,22	124,46	156,33	64,92	70,80	96,15	55,42
Poland	75,36	36,65	211,02	46,81	95,84	14,31	40,68	65,84	106,15	55,67
Netherlands	175,53	220,98	280,54	139,01	98,20	112,24	159,42	105,23	138,59	93,71
Malta	88,73	87,58	233,14	106,98	105,75	53,20	17,10	128,61	187,23	59,02
Latvia	75,99	52,51	138,30	126,72	73,84	35,70	56,34	59,09	100,25	50,82
Luxembourg	177,95	236,20	236,20	122,67	81,91	126,84	90,16	141,04	189,20	84,75
Lithuania	119,47	54,29	187,53	97,67	101,13	98,82	108,96	52,43	64,72	53,17
Italy	61,45	111,14	121,18	65,21	94,88	116,85	69,05	96,18	87,01	80,36
Ireland	175,23	171,08	149,53	83,10	113,90	118,67	84,10	53,36	200,86	128,70
Hungary	51,48	66,76	144,47	53,39	106,56	30,39	60,65	44,50	150,19	84,68
Croatia	65,70	50,24	71,37	44,83	117,94	85,99	67,50	32,81	80,89	38,29
France	159,41	140,94	143,14	159,11	108,90	113,97	103,08	78,89	93,00	88,67
Finland	198,53	173,53	321,58	158,75	168,70	153,29	167,92	118,73	93,54	90,08
Spain	177,85	105,21	197,25	90,40	83,58	40,92	67,93	70,12	114,85	83,96
Greece	92,69	77,99	76,73	61,50	85,37	130,97	129,70	39,13	57,37	67,58
Estonia	140,54	121,60	137,96	104,89	123,33	95,05	133,79	112,74	79,11	66,43
Denmark	206,89	224,56	329,62	167,89	139,59	86,59	154,14	137,40	118,34	73,85
Germany	108,73	105,35	169,76	138,36	190,03	122,38	139,59	119,78	113,88	119,12
Czechia	84,42	83,72	121,55	66,78	121,71	86,72	92,67	51,69	148,78	94,68
Cyprus	118,76	145,25	140,13	86,90	101,07	73,55	61,41	98,03	75,62	98,49
Bulgaria	60,08	29,42	74,59	13,45	52,91	23,97	35,59	77,89	120,10	40,26
Belgium	133,53	190,72	158,14	131,08	158,96	133,63	168,53	81,73	95,46	103,90
Austria	143,26	167,85	130,65	109,55	127,20	135,09	187,75	126,30	75,42	83,94

Source: the study based on European Innovation Score board (2019)

Table 9

The composition of the selected clusters of the EU countries and Ukraine according to the indicators of the European innovation scoreboard (EIS)2019

Cluster	Countries
Cluster 1	Finland, Netherlands, Denmark, Sweden
Cluster 2	Belgium, Germany, Austria, France, Estonia
Cluster 3	Ireland, Luxembourg
Cluster 4	Malta
Cluster 5	Cyprus, Italy, Portugal, Slovenia, Lithuania, Spain
Cluster 6	Croatia, Greece, Czech Republic, Hungary, Slovakia
Cluster 7	Ukraine, Romania, Poland, Bulgaria, Latvia

Source: own calculations based on EIS (2019)

Table 10

Source data for correlation between development factors and indices that determine global and technological competitiveness of Ukraine

	Expenditure on education, % of GDP	Graduates in science and technology, %	Quality of scientific research institutions	Ratio of employees involved in R&D to the employedpopulation,%	Ratio of R&D expenditures to GDP,%	FDI inflows (% of GDP)	ICT access	State of cluster development	Ratio of high-tech products export to industrial exports, %	ICT services exports, % of total exports of services	PCT patents applications, million pop.	Income from the intellectual property use, mln $
	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
2011	5,9	26,3	3,6	0,947	0,738	4,417	47,9	28,6	3,277	17,923	0,3	107
2012	5,9	26,3	3,7	0,877	0,754	4,651	48,6	35,4	4,737	19,34	2,1	124
2013	6,2	25,6	3,6	0,822	0,759	2,46	52,7	31,17	4,134	22,204	2,9	167
2014	6,7	25,6	3,8	0,792	0,649	0,634	61,6	33,3	4,129	30,482	3,2	118
2015	6,7	25,5	4,2	0,778	0,617	3,351	62,7	32,5	3,994	31,442	3,6	85
2016	6	25,5	4,2	0,627	0,700	3,689	64,8	32,5	3,295	31,756	3,9	73
2017	5,9	26,7	3,9	0,608	0,600	2,165	66	35,5	2,795	33,513	3,6	72
2018	5,9	26,7	3,9	0,600	0,600	2,6	66	35,5	2,900	31,3	3,7	74
2019	5	24,2	3,5	1,100	0,4	3,2	66,5	37,3	2	31,7	3,9	74

	Global Competitiveness Index	Technological readiness (GCI)	Innovation (GCI)	Global Innovation Index	World Digital Competitiveness Ranking
	У1	У2	У3	У4	У5
2011	4,000	3,74	3,1	35,00	-
2012	4,140	3,6	3,2	36,10	-
2013	4,050	3,28	3,0	35,80	54
2014	4,140	3,5	3,2	36,30	50
2015	4,030	3,45	3,4	36,45	59
2016	4,000	3,58	3,4	35,72	59
2017	4,110	3,8	3,4	37,62	60
2018	4,010	3,84	3,4	43,00	58
2019	4,120	3,9	3,5	47,00	60

Source: own calculations based on GCIWEF (2011-2019), GII (2011-2019), IMDWDCR (2017-2019)

Table 11

Correlation between factors of development and indices that determine the global and technological competitiveness of Ukraine

	GlobalCompetitivenessIndex	Technological readiness (GCI)	Innovation (GCI)	GlobalInnovationIndex	WorldDigitalCompetitivenessRanking
Expenditure on education, % of GDP	-0,12381	-0,729	-0,37023	-0,70557	-0,57762
Graduates in science and technology, %	-0,19581	0,0893	-0,30045	-0,41941	-0,01487
Quality of scientific research institutions	-0,40208	-0,203	0,477786	-0,30827	0,268272
Ratio of employees involved in R&D to the employed population,%	0,324322	0,096	-0,19326	0,288689	-0,05928
Ratio of R&D expenditures to GDP,%	-0,2739	-0,623	-0,75517	-0,87914	-0,47486
FDI inflows (% of GDP)	-0,33551	0,165	0,033029	-0,10409	0,802082
ICT access	0,015384	0,371	0,843931	0,565446	0,604922
Stateofclusterdevelopment	0,593752	0,516	0,594049	0,726723	0,475249
Ratio of high-tech products export to industrial exports, %	0,146648	-0,789	-0,6702	-0,74305	-0,6957
ICT services exports, % of total exports of services	0,063871	0,270	0,80242	0,447864	0,514709
PCT patents applications, million pop.	0,146025	0,040	0,702985	0,470915	0,787447
Income from the intellectual property use, mln $	0,172407	-0,730	-0,90995	-0,47957	-0,73414

Source: own calculations based on GCIWEF (2011-2019), GII (2011-2019), IMDWDCR (2017-2019)

Table 12

Source data for multiple regression analysis between the Global Competitiveness Index (GCI WEF) and selected factors

	Global Competitiveness Index	State of cluster development	FDI inflows (% of GDP)	Ratio of high-tech products export to industrial exports, %
	У1	X1	X2	X3
2011	4,000	28,6	4,417	3,277
2012	4,140	35,4	4,651	4,737
2013	4,050	31,17	2,46	4,134
2014	4,140	33,3	0,634	4,129
2015	4,030	32,5	3,351	3,994
2016	4,000	32,5	3,689	3,295
2017	4,110	35,5	2,165	2,795
2018	4,010	35,5	2,6	2,900
2019	4,120	37,3	3,2	2,000

Source: own calculations based on GCI WEF (2011-2019)

Table 13

Results of multiple regression analysis between the Global Competitiveness Index (GCI WEF) and selected factors

Multiple R	0,747846
R^2	0,559273
F	2,114964
Significance F	0,216959
Y	3,461275
X1	0,015957
X2	-0,01125
X3	0,030031

Source: own calculations based on GCI WEF (2011-2019)

Table 14

Source data for multiple regression analysis between Technological Readiness (composed of GCI WEF) and selected factors

	Technological readiness (GCI)	Ratio of high-tech products export to industrial exports, %	Graduates in science and technology, %	Income from the intellectual property use, mln $
	У2	X1	X2	X3
2011	3,74	3,277	26,3	107
2012	3,6	4,737	26,3	124
2013	3,28	4,134	25,6	167
2014	3,5	4,129	25,6	118
2015	3,45	3,994	25,5	85
2016	3,58	3,295	25,5	73
2017	3,8	2,795	26,7	72
2018	3,84	2,900	26,7	74
2019	3,9	2,000	24,2	74

Source: own calculations based on GCI WEF (2011-2019)

Table 15

Results of multiple regression analysis between Technological Readiness (composed of GCI WEF) and selected factors

Multiple R	0,867296
R^2	0,752202
F	5,059245
Significance F	0,056462
Y	2,535193
X1	-0,1627
X2	0,070742
X3	-0,00166

Source: own calculations based on GCI WEF (2011-2019)

Table 16

Source data for multiple regression analysis between Innovation (GCI WEF) and selected factors

	Innovation (GCI)	Quality of scientific research institutions	ICT access	Income from the intellectual property use, mln $
	У3	X1	X2	X3
2011	3,1	3,6	47,9	107
2012	3,2	3,7	48,6	124
2013	3,0	3,6	52,7	167
2014	3,2	3,8	61,6	118
2015	3,4	4,2	62,7	85
2016	3,4	4,2	64,8	73
2017	3,4	3,9	66	72
2018	3,4	3,9	66	74
2019	3,5	3,5	66,5	74

Source: own calculations based on GCI WEF (2011-2019), GII (2011-2019)

Table 17

Results of multiple regression analysis between Innovation (GCI WEF) and selected factors

Multiple R	0,945408
R^2	0,893797
F	14,02652
Significance F	0,007198
Y	3,110847
X1	0,000642
X2	0,008395
X3	-0,0033

Source: own calculations based on GCI WEF (2011-2019), GII (2011-2019)

Table 18

Source data for multiple regression analysis between Global Innovation Index (GII) and selected factors

	Global Innovation Index	Ratio of R&D expenditures to GDP, %	State of cluster development	ICT services exports, % of total exports of services
	У4	X1	X2	X3
2011	35,00	0,738	28,6	17,923
2012	36,10	0,754	35,4	19,34
2013	35,80	0,759	31,17	22,204
2014	36,30	0,649	33,3	30,482
2015	36,45	0,617	32,5	31,442
2016	35,72	0,700	32,5	31,756
2017	37,62	0,600	35,5	33,513
2018	43,00	0,600	35,5	31,3
2019	47,00	0,4	37,3	31,7

Source: own calculations based on GII (2011-2019)

Table 19

Results of multiple regression analysis between Global Innovation Index (GII) and selected factors

Multiple R	0,924411
R^2	0,854537
F	9,790969
Significance F	0,015561
Y	50,80415
X1	-32,7322
X2	0,4271
X3	-0,21111

Source: own calculationsbased on GII (2011-2019)

Table 20

Source data for multiple regression analysis between the Digital Competitiveness Index (IMD WDCR) and selected factors

	World Digital Competitiveness Ranking	FDI inflows (% of GDP)	Ratio of high-tech products export to industrial exports, %	PCT patents applications/million pop.
	У5	X1	X2	X3
2013	54	2,46	4,134	2,9
2014	50	0,634	4,129	3,2
2015	59	3,351	3,994	3,6
2016	59	3,689	3,295	3,9
2017	60	2,165	2,795	3,6
2018	58	2,6	2,900	3,7
2019	60	3,2	2	3,9

Source: own calculations based on IMD WDCR (2013-2019)

Table 21

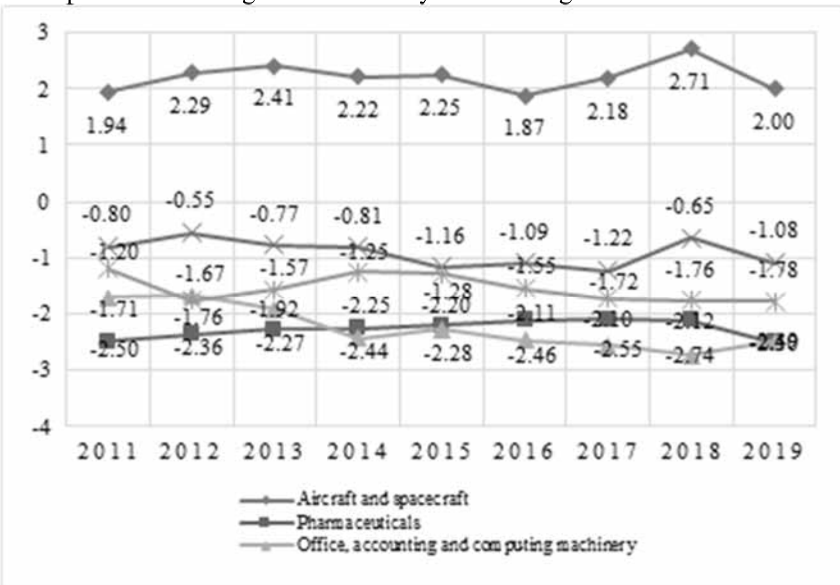
Results of multiple regression analysis between the Digital Competitiveness Index (IMD WDCR) and selected factors

Multiple R	0,916997
R^2	0,840884
F	5,284739
Significance F	0,102451
Y	51,52405
X1	2,106491
X2	-1,71027
X3	1,651747

Source: own calculationsbased on IMDWDCR (2013-2019)

Figure 1

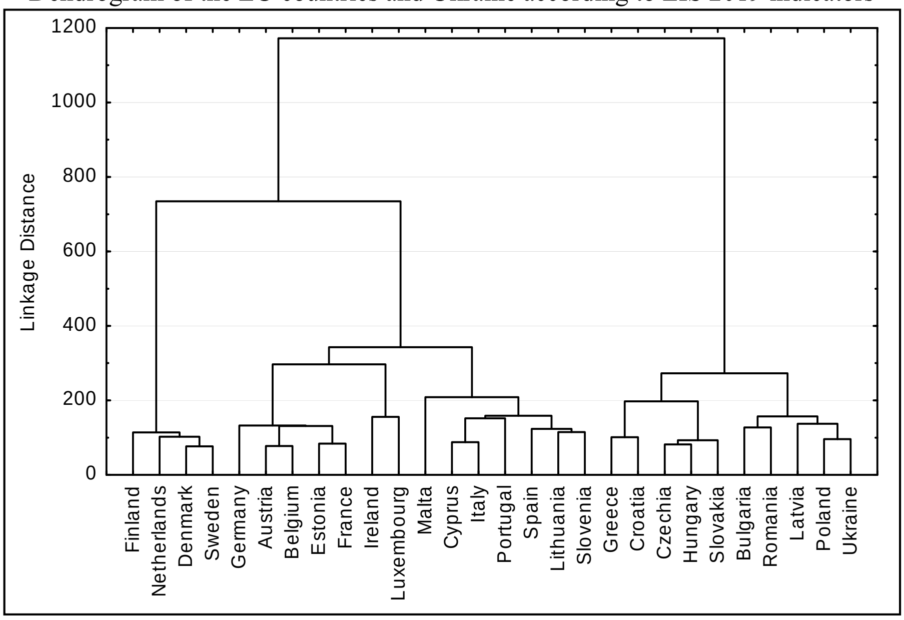
The comparative advantages of Ukraine by the main high-tech industries 2011-2019



Source: own calculations based on United Nations Commodity Trade Statistics Database (2011-2019)

Figure 2

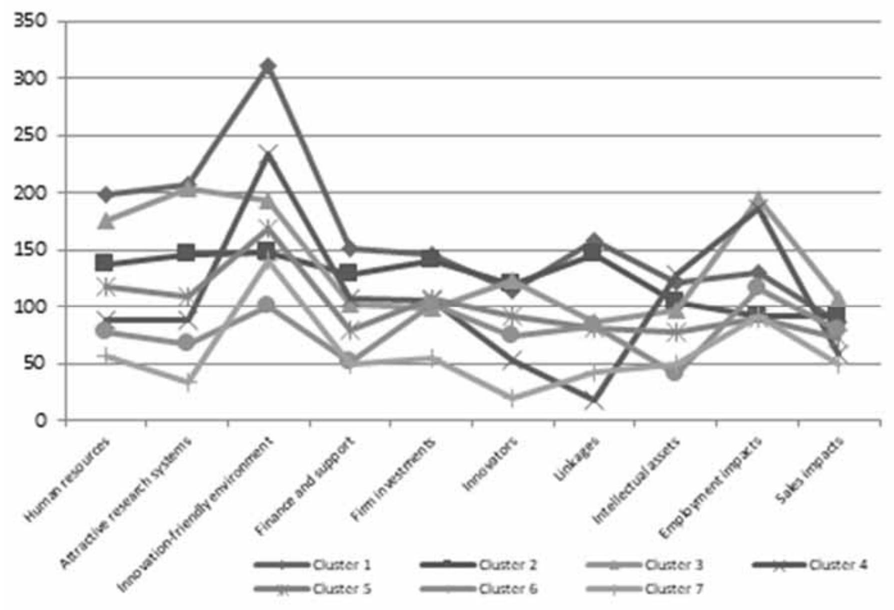
Dendrogram of the EU countries and Ukraine according to EIS 2019 indicators



Source: own calculations based on EIS (2019)

Figure 3

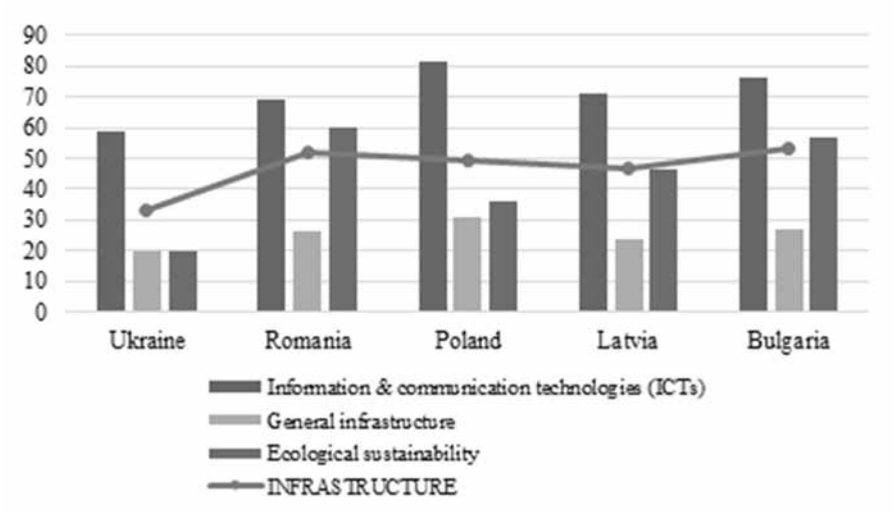
State of development of received clusters by EIS 2019indicators



Source: own calculations based on EIS (2019)

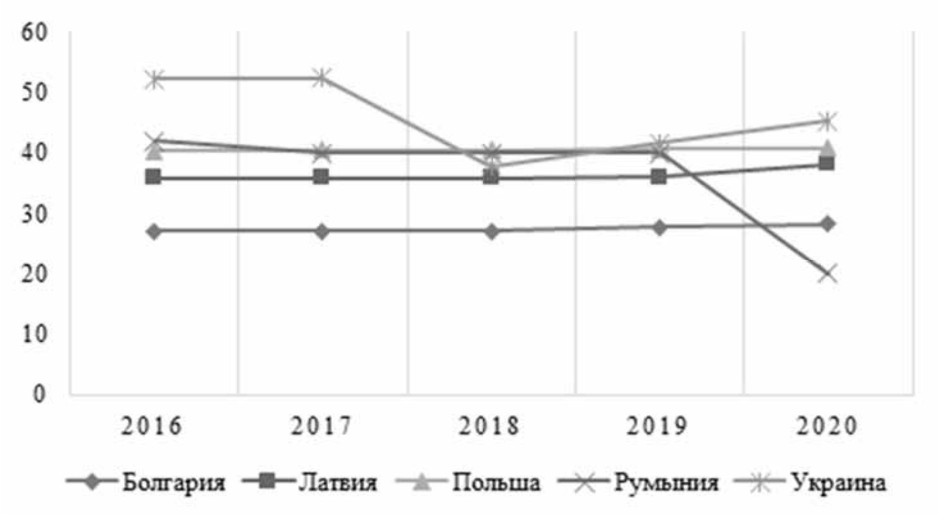
Figure 4

State of development of Infrastructure in the countries of the seventh cluster by GII 2020 indicators



Source: the study based on Global Innovation Index (2020)

Figure 5
State of development of tax system in the countries of the seventh cluster by DB 2020 indicators



Source: the study based on Doing Business (2020)

Figure 6
State of development of Labour market in the countries of the seventh cluster by GCI WEF (2020) indicators

Source: the study based on GCI WEF (2020)