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CHALLENGES AND OPPORTUNITIES IN THE 'BUSINESS-EDUCATION-SCIENCE' SYSTEM IN THE CONTEXT OF INNOVATION DEVELOPMENT: CLUSTER ANALYSIS

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Abstract: *The purpose of this article is to characterise challenges and opportunities in the 'business-education-science' system in the context of innovation development based on cross-country cluster analysis. The article examines the relationship between science, education and business and their mutual influence on modern society. The main challenges facing science, education and business are considered, and opportunities for cooperation between these fields to overcome them are identified. Key factors that influence the effectiveness of scientific research, the quality of education, and the success of business are also determined, with an emphasis on the important role of cooperation in the 'business-education-science' system in ensuring their impact. To reach article's purpose, a complex methodology was applied, which includes the following stages: collection of information about the current state of science, education, and business; a review of expert opinions and analytical reports on the problems of the interaction of science, education and business; methods of cross-country cluster analysis using STATISTICA 10 software (the k-Means method, the square of the Euclidean metric, etc. for a comparative analysis between 19 countries from a sample to find out which of them have better indicators in the respective fields). The statistical base is formed from the European Union and the WIPO data, which cover 10 key indicators in the context of the development of science, education and business and their affect the country's competitiveness in the global world. As a result, there are two formed clusters: the first includes the USA and China that have the highest level of education-science-business development and the second cluster includes other countries from the sample with a less developed education-science-business sector. For these countries the recommendations have been developed to strengthen their education-science-business sector, in particular: creating favourable conditions for investing in science and business, attracting talented scientists, and supporting their activities, increasing allocations for education, and improving the quality of education, strengthening partnerships between universities and enterprises to create innovative projects and other activities. The obtained results can be useful for further research and for making managerial decisions at different levels of government in the context of innovation development, including through the strengthening of coopetition between business, education, and science.*

Keywords: coopetition, innovation, patents, research, R&D investments, R&D products, technologies.
JEL Classification: I23, L21, O11, O32.

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Introduction

In today's world, science, education, and business are interconnected fields that have great potential for cooperation and development. The need for interaction between these areas is growing not only due to rapid scientific and technical development, but also due to changes in business and economy. Understanding the relationships between these fields is critical to producing high-quality scientific results that can be used in business and industry. Cooperation between science and business is a source of new innovations and production technologies that ensure economic development and improve the quality of life.

Therefore, the study of the relationship between science, education and business is of great importance for understanding the current situation and the future development of society. This article considers how the interaction of science, education, and business affects the development of society, and explores what specific mechanisms contribute to increasing the effectiveness of scientific research, improving the quality of education, and ensuring commercial success.

The current state of interaction between science, education and business is complex and diverse. There are many examples of successful collaborations between these industries that lead to innovation, new technologies and business development. However, there are also many challenges that hinder this cooperation, leading to a loss of potential and efficiency. Research and innovation are key elements of business and economic development. But insufficient financing of scientific research and insufficient support from the state and innovative enterprises lead to a decrease in the level of scientific research results and a loss of competitiveness.

Education plays an important role in the development of science and business, providing qualified personnel and scientific personnel. Nevertheless, the education system may be insufficient to meet the demands of the labour market and innovation, which leads to a shortage of qualified workers and hinders the development of scientific research. Enterprises that are open to scientific and educational cooperation quite often encounter certain difficulties. For example: companies may have a limited view of the long-term prospects of scientific research and innovation because they focus on short-term financial indicators; cooperation with science and education can be difficult, as these fields have different goals and values, which leads to a conflict of interests; there are also cases when commercial companies finance scientific research, which affects the results of research and the use of the obtained results.

Therefore, the interaction between science, education and business has great potential for the development of society and meeting its needs for new knowledge and technologies. But for this, it is necessary to create favourable conditions for cooperation between these industries and ensure their interaction at different levels: regional, national, international.

That is why article's purpose is to characterise challenges and opportunities in the 'business-education-science' system in the context of innovation development based on cross-country cluster analysis.

Literature Review

Considering the works of professional experts, their works should be divided into two categories. The first category includes experts who believe that science and business can interact to ensure commercial success and scientific breakthrough. For example, high technology can be used to solve business problems, and business can provide funding for scientific research. The second category includes the works of experts who say that science and education should have a certain independence from business in order to ensure scientific objectivity and freedom of choice of research directions. They recognize the need for interaction between these industries to promote economic development and create jobs. At the same time, both categories of expert research indicate the need to improve the education system for the proper training of specialists in the field of science and technology, who can interact with companies and help solve problems.

In particular, the importance of the interaction of science, education and business is emphasized in research by Peter Drucker, a scientist and expert in the field of innovation development. He wrote that these industries must work together to achieve innovation development and ensure competitiveness. Drucker also believed that education should impart not only knowledge and skills, but also the ability to act in unstable and changing situations. He emphasized the need to develop a 'creative person' capable of self-improvement and self-organization (Alum, 1986).

The following expert in the field of science and economics, Richard Florida, proposes the concept of the 'creative class' as an important factor in the development of economies based on knowledge. Creative classes are formed by people who work in fields related to science, technology, and innovation, have higher education and creative abilities. Florida emphasizes the importance of creating conditions for the development of the creative class: providing affordable and quality education, creating an innovation environment, and supporting scientific research (Florida, 2003).

Michael Porter, professor of economics and management at the Harvard Business School, believes that a country's competitiveness depends on its ability to create innovations (Porter, 1990).

Alexandre et al. emphasize the need to ensure interaction between universities and companies to promote innovation development: universities should be more active in cooperation with companies, and companies should actively invest in research and development conducted by universities (Alexandre et al., 2019).

The Scientific and Technical Council of the Ministry of Education and Science of Ukraine in its publication 'Interaction of science, education and business in the context of ensuring innovation development of the country' notes that the interaction of science, education and business has great potential for the development of the national economy and ensuring the competitiveness of Ukraine. The organization believes that it is necessary to create a national system of innovation development that would ensure effective interaction of science, education, and business in Ukraine (Naukovo-tekhnichna rada, 2018).

The American House of Representatives in the report 'The Role of Research Universities in Ensuring American Competitiveness' notes that the development of science and education should be a priority area of state activity. Universities should be the main sources of scientific research and technological innovation, as well as facilitate interaction with business and government (US House of Representatives, 2018).

The Organisation for Economic Co-operation and Development (OECD) published the report 'Innovation and Growth: Rationale for an Innovation Strategy', which emphasizes the importance of interaction between science, education, and business to ensure innovative development and create new jobs. The organization recommends that states promote the interaction of scientific institutions and universities with business and create favourable conditions for technological start-ups (OECD, 2010).

Another organization that gave its opinion on the interaction of science, education and business is the European Research Institute (ERI). In their article 'Science, education and business: Why Europe needs a new model of innovation', they state that a new approach to innovative activity in Europe is needed, which would combine the strengths of science, education, and business. The authors of the article emphasize that the interaction between these industries is a key success factor in innovation development, but for this it is necessary to create new cooperation mechanisms. They propose the creation of innovation ecosystems that would combine scientific, educational and business organizations into a single network aimed at creating new technologies and products (European Research Institute, 2013).

Therefore, organizations actively support the interaction of science, education, and business. Some develop special programs and projects aimed at increasing the level of scientific research and development of business ideas.

The opinions of experts and scientists confirm the need to develop interaction between science, education, and business to achieve innovation development. Such interaction will benefit universities, business, and society in general, but it is necessary to create a favourable infrastructure and legal framework for this.

Methodology and research methods

To analyse the interaction of science, education and business, a complex methodology was applied, which includes the following stages: 1) collection of information about the current state of science, education, and business (based on scientific articles, studies, statistical data, reports of international organizations and other sources related to this topics); 2) a review of expert opinions on the interaction of science, education and business (for this purpose, the articles of experts working in the field of science, education and business were studied); 3) a review of analytical reports of international organizations on the problems of the interaction of science, education and business; 4) methods of cluster analysis (for a comparative analysis between countries and finding out which of them have better indicators in the respective fields) were performed in STATISTICA 10 using the Analysis/Multivariate Exploratory Analysis/Cluster Analysis procedure. The k-Means method was used as a clustering method using the distance metric between clusters – the square of the Euclidean metric.

To compare and classify countries according to indicators related to science, education, and business, it is proposed to conduct a cluster analysis for 19 countries of the world: Austria, Bulgaria, Belgium, Croatia, the Czech Republic, Denmark, Great Britain, Greece, Spain, Italy, Estonia, Cyprus, USA, China, Japan, Germany, Israel, South Korea, Ukraine.

The statistical base uses open data from the European Union and the WIPO in 2021, which cover key aspects of the development of science, education and business and affect the country's competitiveness in the global world:

K1 – the level of investment in science and technology (determines the total the level of investment in science and technology in the country and the importance of how much the country invests in scientific research and development) (Eurostat, n.d.e);

K2 – investment in science and technology, GDP% (determines the ratio of investment in science and technology to the gross domestic product (GDP) and allows to compare the level of investment in science and technology in different countries, taking into account their level of economic development) (Eurostat, n.d.a);

K3 – investment in research and development, million US dollars (indicates total investment in research and development in the country) (Eurostat, n.d.b);

K4 – number of patents registered in the country (characterizes the level of scientific research and innovation in the country) (WIPO, n.d.);

K5 – the number of higher education institutions (indicates the level of access to education in the country and shows how well the country invests in the development of education and scientific research, and how well it is able to provide its citizens with an adequate level of education) (Eurostat, n.d.c);

K6 – the number of scientific publications (determines the works published by scientists in relevant scientific publications and determines the level of activity and success of research activities in the country) (Scimago, n.d.);

K7 – volume of scientific and technical products (indicates the total volume of scientific and technical products that were developed and produced in the country and determines the level development and competitiveness of the country's scientific and technical industry) (Eurostat, n.d.f);

K8 – Global Innovation Index (GII) (determines cooperation between science and business and shows the presence of structural connections between scientific research and business, which positively affects the innovation development of the country) (WIPO, 2021);

K9 – financing of scientific infrastructure (represents the total amount of financing of infrastructure projects and objects related to scientific and research works in the country) (European Commission, n.d.);

K10 – the number of scientists and business specialists working in scientific and research institutes, as well as in business structures (characterizes the availability and development of human resources in the country, which can be an important factor for the development of science, technology and innovation) (Eurostat, n.d.d).

Results

The input data of the study are presented in Table 1.

Table 1. Input data

Country/ Indicator	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10
Austria	3,19	3,19	9 475,00	880,00	65,00	36 803,00	14,80	32,00	1 215,00	45 868,00
Belgium	2,51	2,46	10 754,00	1 284,00	28,00	37 145,00	24,30	7,00	2 862,00	45 011,00
Bulgaria	0,78	0,97	539,00	139,00	52,00	7 690,00	1,10	-	436,00	25 156,00
Croatia	0,86	0,97	321,00	18,00	34,00	4 040,00	0,60	-	400,00	14 074,00
Czech Republic	1,78	2,20	2 638,00	497,00	77,00	24 117,00	14,20	5,00	2 011,00	84 085,00
Denmark	3,02	3,14	5 356,00	1 174,00	8,00	30 211,00	13,70	10,00	2 187,00	54 358,00
United Kingdom	1,70	1,71	42 987,00	5 080,00	186,00	172 783,00	25,90	11,00	27 605,00	330 590,00
Greece	1,00	1,02	3 024,00	321,00	44,00	11 514,00	1,20	41,00	1 342,00	43 910,00
Spain	1,24	1,24	16 814,00	2 182,00	85,00	82 520,00	6,50	19,00	5 409,00	203 286,00
Italy	1,23	1,24	25 732,00	2 951,00	97,00	90 343,00	6,70	20,00	5 307,00	204 324,00
Estonia	1,45	1,45	239,00	63,00	9,00	1 783,00	1,02	55,00	41,00	1 704,00
Cyprus	0,22	0,49	38,00	4,00	8,00	935,00	0,10	-	132,00	3 820,00
USA	4,50	2,80	608 000,00	355 455,00	5 300,00	619 163,00	549,00	1,00	287 087,00	6 418 141,00
China	4,00	2,10	536 000,00	1 536 100,00	3 000,00	528 263,00	372,00	34,00	278 534,00	5 312 326,00
Japan	3,60	3,20	170 400,00	197 548,00	1 000,00	152 628,00	163,00	7,00	142 371,00	1 734 000,00
Germany	3,00	2,90	126 500,00	66 022,00	400,00	107 526,00	123,00	9,00	111 527,00	868 155,00
Israel	4,90	4,90	16 500,00	12 732,00	50,00	95 931,00	31,30	4,00	10 605,00	140 464,00
South Korea	4,20	4,50	85 800,00	182 527,00	400,00	70 178,00	146,00	2,00	55 715,00	754 905,00
Ukraine	3,14	0,36	927,80	1 445,00	962,00	29 853,00	3,60	341,60	1 476,00	323 000,00

Source: built by the authors based on (Eurostat, n.d.a – n.d.f; WIPO, 2021, n.d.; European Commission, n.d.; Scimago, n.d.)

Cluster analysis was performed in STATISTICA 10 using the Analysis/Multivariate Exploratory Analysis/Cluster Analysis procedure. The k-Means method was used as a clustering method using the distance metric between clusters – the square of the Euclidean metric. The data standardization procedure was also carried out using the tools of the STATISTICA package, since the input indicators were measured in different measurement units. So, the process of cluster analysis converged in 1 iteration. The number of clusters is 2 (Figure 1).

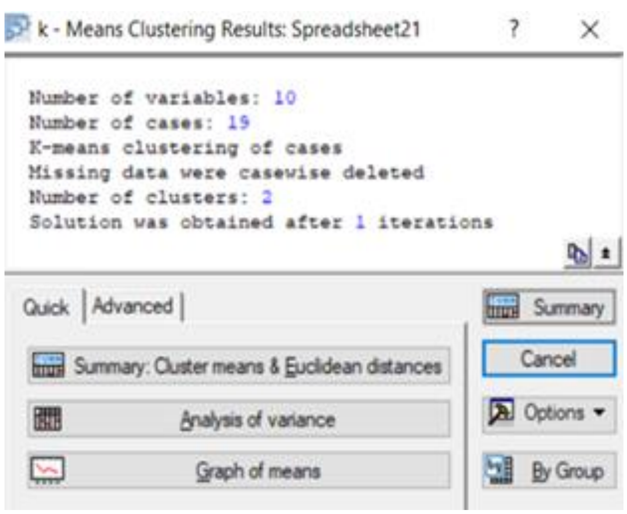

Figure 1. Results of cluster analysis using the k-Means method

Source: built by the authors using STATISTICA software.

The quality of the cluster analysis was confirmed by the results of the values of Euclidean distances (Table 2), average values of clusters, dispersion analysis, level of significance, graph of averages of each cluster. So, in cluster analysis, the distance between clusters is used to determine how different the clusters are from each other. The smaller the distance between the clusters, the greater the similarity between them. Therefore, the distance between the first and second cluster is 4.805265. This means that these clusters are moderately different from each other, but still different enough to be separated from other clusters.

Table 2. Euclidean distances

Cluster number	Cluster 1	Cluster 2
Cluster 1	0	3,258
Cluster 2	4,805265	0

Note: The distance between clusters is below the main diagonal, the squares of the distances are above the main diagonal.

Source: built by the authors using STATISTICA software.

The values on the diagonal of the matrix are equal to zero, they correspond to the distance between each cluster and itself, that is, they are always equal to zero. The squares above the diagonal of the matrix correspond to the distances between each pair of clusters. The matrix contains only one distance between the first and second cluster, and therefore, as previously stated, only two clusters were identified in the analysis. Cluster averages are determined to get an idea of the typical characteristics of the objects included in each cluster. The values of the average indicators for the cluster help to understand what characteristics are common to each cluster and distinguish it from other clusters (Table 3).

Table 3. Average indicators by cluster

Indicator	Cluster 1	Cluster 2
The level of investment in science and technology	4	2,2
Investment in science and technology (% of GDP)	2	2,1
Investments in the GDR (million dollars)	572000	30473,2
Number of patents	945778	27933,4
Number of higher and secondary educational institutions	4150	206,2
Number of scientific publications	573713	56235,3
Volume of scientific and technical products (billion dollars)	461	33,9
Cooperation between science and business (GII)	18	33,2
Financing of scientific infrastructure (million dollars)	282811	21802,4

Source: built by the authors using STATISTICA software.

It can be said that countries with the lowest level of educational development are included in cluster 2, and countries with the highest level of education are included in cluster 1. Dispersion analysis is an important stage of cluster analysis. It allows to assess how significant the differences between clusters are. If the differences between the clusters are statistically significant and do not exceed 5%, it means that the cluster analysis successfully identified various groups according to the given characteristics (Table 4). The larger the value of intergroup variance (Between SS) and the smaller the value of intragroup variance (Within SS), the better the clustering results.

Table 4. Analysis of variance for 2 clusters

Indicator	Intergroup variance	Degrees of freedom	Intragroup variance	Degrees of freedom	F-test	p-value
K_1	7,340092E+00	1	2,866062E+01	17	4,3538	0,042301
K_2	2,018830E-01	1	2,949461E+01	17	0,1164	0,007372
K_3	5,247654E+11	1	4,252206E+10	17	209,7973	0,000539
K_4	1,507520E+12	1	7,606045E+11	17	33,6941	0,000021
K_5	2,783302E+07	1	4,238468E+06	17	111,6350	0,000000
K_6	4,791909E+11	1	4,951253E+10	17	164,5290	0,003607

Table 4 (cont.). Analysis of variance for 2 clusters

Indicator	Intergroup variance	Degrees of freedom	Intragroup variance	Degrees of freedom	F-test	p-value
K_7	3,255973E+05	1	6,204661E+04	17	89,2096	0,000000
K_8	4,384471E+02	1	1,054861E+05	17	0,0707	0,004794
K_9	1,219083E+11	1	2,872241E+10	17	72,1541	0,000000
K_{10}	5,568519E+13	1	3,876138E+12	17	244,2246	0,000000

Source: built by the authors using STATISTICA software.

The level of significance for all indicators is less than 0.05. Indicators: K1, K3, K8, K10 have a large indicator of external group dispersion and a smaller indicator of intragroup dispersion. Therefore, these indicators are acceptable and satisfactory. Indicators: K2, K4, K5, K6, K7, K9 – on the contrary, and this is not good enough. This means that the means between groups are quite similar, but the mean within each group can vary significantly.

To compare the values of in-group and out-group variance, variance analysis was conducted for 3 clusters.

Table 5. Analysis of variance for 3 clusters

Indicator	Intergroup variance	Degrees of freedom	Intragroup variance	Degrees of freedom	F-test	p-value
K_1	1,423032E+01	2	2,177040E+01	16	5,2292	0,017883
K_2	7,539228E+00	2	2,215727E+01	16	2,7221	0,096048
K_3	5,591071E+11	2	8,180310E+09	16	546,7834	0,000000
K_4	1,560649E+12	2	7,074759E+11	16	17,6475	0,000090
K_5	2,839801E+07	2	3,673472E+06	16	61,8445	0,000000
K_6	4,897646E+11	2	3,893892E+10	16	100,6221	0,000000
K_7	3,697221E+05	2	1,792183E+04	16	165,0376	0,000000
K_8	3,124261E+03	2	1,028003E+05	16	0,2431	0,787013
K_9	1,460469E+11	2	4,583841E+09	16	254,8899	0,000000
K_{10}	5,820780E+13	2	1,353524E+12	16	344,0370	0,000000

Source: built by the authors using STATISTICA software.

Indicators: K2, K6, K7, K8, K10 have a large indicator of external group dispersion and exceed the indicator of intragroup dispersion. As for K1, K3, K4, K5, K9 indicators, the opposite is true. Therefore, the results almost did not change, so it was decided to analyse 2 clusters in the further study. The graph of averages is a tool that helps to visualize the average values of each of the indicators for each cluster. This plot is an important element in cluster analysis, it allows you to compare the mean values between clusters and assess their significance. The higher the line or bar, the higher the average value of the indicator for the cluster (Figure 2).

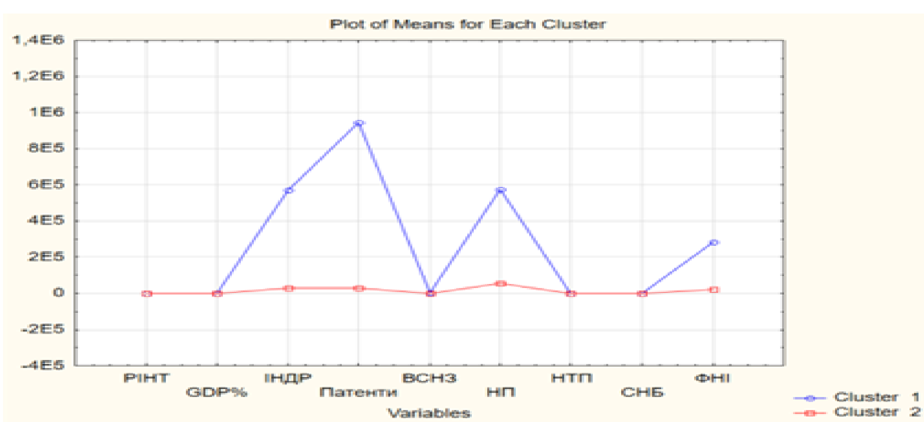

Figure 2. Graph of averages

Source: built by the authors using STATISTICA software.

Each line is the cluster mean. Each point is the mean of the cluster in a particular variable.

The graph shows that the highest average values of the level of education development are the number of patents, the number of scientific publications and investments in the R&D, and the lowest are investments in science and technology, the number of higher and secondary educational institutions, the volume of scientific and technical products, cooperation between science and business. This means that for clusters with a higher level of educational development (cluster 1), the most significant factors are the number of patents, the number of scientific publications and investments in the R&D. These indicators may indicate activity in the field of science and technology, as well as the presence of highly qualified scientists and researchers.

In clusters with a lower level of educational development (cluster 2), less significant factors are investments in science and technology, the number of higher and secondary educational institutions, the volume of scientific and technical products, and cooperation between science and business. This may indicate insufficient attention to the development of science and education in these countries and a low level of cooperation between research institutions and business. The remaining types occupy an intermediate position between these two extremes.

Consider such a characteristic of cluster analysis as elements of clusters and distances.

Clustering elements and distances are key characteristics of cluster analysis. They allow a better understanding of how clusters are formed and how they relate to each other. So, this shows which clusters and which countries are included (Table 6).

Table 6. Content of the 1st and 2nd clusters

Country	Cluster 1 (2)	Country	Cluster 2 (17)
	Distance		Distance
USA	256431	Austria	77494,5
China	256431	Belgium	77663,2
		Bulgaria	85424,6
		Croatia	89042,7
		Czech Republic	66385,8
		Denmark	75145,6
		United Kingdom	40258,9
		Greece	79348,5
		Spain	29656,1
		Italy	29824,7
		Estonia	92976,6
		Cyprus	92384,4
		Japan	465443,5
		Germany	189539,2
		Israel	48539,2
		South Korea	157278,7
		Ukraine	19975,3

Source: built by the authors using STATISTICA software.

Thus, the qualitative cluster analysis procedure made it possible to identify countries that have common problems and challenges in scientific, educational, and economic development. This made it possible to develop recommendations and strategies for the further development of these areas in these countries.

Based on the results of the cluster analysis, it was concluded that the USA and China have the highest level of education-science-business development. The second cluster includes countries with a less developed education-science-business sector.

The USA and China have the highest level of education-learning-business interaction for several reasons:

1) investment in science and technology: The USA and China are making significant investments in science and

technology, which allows for the development of new ideas and products, forcing businesses to work more closely with scientists and researchers;

2) the number of patents and scientific publications: the US and China have the largest number of patents and scientific publications, demonstrating a high level of research and development and the ability to transform scientific developments into new products and services;

3) close cooperation between education and business: the USA and China have a developed system of cooperation between education and business, which allows to create innovative products and develop new technologies. In these countries, firms can partner with universities and research institutes to attract new ideas and talent.

The countries included in the second cluster need to take a number of measures in order to increase their level of development. In particular, ensure a sufficient level of funding for scientific research and involve business and the scientific community in cooperation. It is important to create favourable conditions for the development of innovations and technologies in business, as well as to ensure the quality of education and the training of qualified personnel for the development of scientific research and business.

Creating favourable conditions for the development of innovations and technologies in business and ensuring the quality of education and training of qualified personnel for the development of scientific research and business are important tasks that can be accomplished with the help of various initiatives and policies.

One of the possible initiatives is the creation of special programs that provide financial and informational support for enterprises. Such programs can provide access to loans, scholarships, grants, research, and other resources that can help businesses grow and create new innovative products.

To ensure the quality of training and advanced training of qualified personnel, it is important to support educational institutions and provide them with the necessary resources for training. For this, a special funding program can be created to provide the necessary funds to students and pupils. It is also possible to improve the qualifications of teachers and organize scientific conferences. This allows the best teachers and scientists to be involved in the educational process.

Strong links between universities and industry must be built to ensure technology transfer of scientific developments. For this purpose, special programs and initiatives can be created that will promote interaction between the university and the private sector.

In accordance with the requirements of the modern labour market, qualified training and advanced training of students and employees is necessary. To do this, it is possible to create joint educational programs with industry, to involve industry in the processes of training and professional development, to support educational institutions in the field of natural sciences and technologies.

It is also important to ensure the availability of information about scientific achievements and opportunities for cooperation between science and business to provide a more effective exchange of ideas and knowledge. For this purpose, special platforms and sites for communication and cooperation between scientific institutions and companies can be created.

Therefore, creating favourable conditions for the development of innovations and technologies in business and ensuring the quality of education and training of qualified personnel for the development of scientific research and business are important tasks that require the joint efforts of science, education, and business.

Conclusions

This research characterised challenges and opportunities in the 'business-education-science' system in the context of innovation development based on cross-country cluster analysis. It was grounded that development of science, education and business is important for ensuring the sustainable development of society. The interaction between these fields can increase the efficiency of scientific research, the quality of education and promote business development in conditions of rapid technological development. However, to ensure success, it is necessary to solve certain problems that prevent the development of interaction between science, education, and business (insufficient funding of science and an unstable economic environment can reduce business interest in cooperation with scientific institutions; a lack of mutual understanding between universities and business, as well as insufficient cooperation, can make interaction between these industries difficult). The cross-country cluster analysis made it possible to identify countries that have common problems and challenges in scientific, educational, and economic development. It was concluded that the USA and China have the highest level of education-science-business development (the 1st cluster). The 2nd cluster includes other 17 countries from research sample – countries with a less developed education-science-business sector. This made it possible to develop recommendations for the further development of these areas in these countries.

The obtained results can be useful for further research and for making managerial decisions at different levels of government in the context of innovation development, including through the strengthening of coopetition between business, education, and science. At the same time, the study has certain limitations related to the sample of countries, which is planned to be expanded in the future research.

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