ECONOMICS
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QUALITY OF SCIENTIFIC ACTIVITY AS A DETERMINANT OF SOCIO-ECONOMIC DEVELOPMENT

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ABSTRACT. The purpose of this work is to identify the functional links between key indicators of scientific activity and socio-economic development and to check whether the quality of scientific activity and the dynamics of innovative development are the key determinants of socio-economic progress. Following the chosen methodology, the paper forms an array of input data that characterizes the level of scientific and innovative activity, economic and social development. The principal component method is used to identify the most relevant indicators from each group and to introduce three latent variables that denote each group separately. A system of simultaneous structural equations is obtained as a result of establishing functional relationships between manifest and latent variables and building a structural model. In addition, the paper determines two clusters of the studied countries to confirm the obtained results through structural modelling. The study is conducted for 35 European countries based on 33 indicators, which characterize the quality of scientific activity, economic and social development during 2014-2020. The obtained system of structural equations confirms the hypothesis regarding the importance of scientific activity quality in terms of ensuring the socio-economic development of the country.

Introduction

A high level of investment in innovation lays the foundation for economic stability during COVID-19. In 2019, the volume of investment in innovation reached its historical maximum and grew by 8.5%. The World Intellectual Property Organization (WIPO) identified the leading countries by dividing the level of innovative development by the economic development level. According to the data for 2021, four groups were distinguished:
-       countries with high economic development (Switzerland, Sweden, the USA);
-       countries with above-average economic development (China, Bulgaria, Malaysia);
-       countries with average economic development (Vietnam, India, Ukraine);
-       countries with low economic development (Rwanda, Tajikistan, Malawi).

Publishing activity worldwide increased by an average of 7.6% in 2020. In addition, the amount of government spending on research and development increased by 10%, and the number of issued patents by 3.5%. Medical technology, pharmacology and biotechnology fields have been the key drivers of patents. The number of deals with venture capital increased by 5.8% in 2020, which is higher than the average growth rate of the last ten years. Significant growth in the Asia-Pacific region to a great extent offset declines in North America and Europe. Growth rates in Africa, Latin America and the Caribbean increased two times. Thus, the presented trends suggest the following hypothesis: the quality of scientific activity and the dynamics of innovative developments are key determinants of the socio-economic development of the country's national economy.

1. Literature review

The educational component is the basis for the development of the scientific activity. The state's role in managing educational areas contributes to economic growth and the country's intellectual capital and ensures its competitiveness and innovation (Vorontsova et al., 2020; Kasztelnik & Brown, 2020). Supporting a new vector of lifelong learning at the state level (Stuchlý et al., 2020) enables people, regardless of age, to get more prospects for personal development. While identifying and developing methods for assessing the macroeconomic stability of countries with income level, many scientists (Lyeonov et al., 2018) confirm the importance of the regulatory and economic policy in these countries and support various directions of the scientific component. Based on the example of Brazilian higher education institutions, there was a study that identified the interaction between the higher school and the indigenous community (Costa & Figueira-Cardoso, 2022). As a result, it was found that the traditions of one or another community can freely coexist with classical approaches to the organization of the educational process and contribute to the development of innovative activity areas (Artyukhov et al., 2021; Artyukhov et al., 2022).

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Developing soft skills among students, such as stress resistance, the ability to work in a team, and communication skills, contribute to the formation of non-classical scientific communities (Sułkowski et al., 2020; Wodarski et al., 2019; Skrynnyk & Vasylieva, 2020a, 2020b). It was especially actualized in the conditions of remote learning caused by the COVID-19 pandemic (Zaharia et al., 2022; Vasilyeva et al., 2021; Moskovicz, 2021). Scientific studies (Gad & Yousif, 2021; Shvindina et al., 2022; Dźwigoł, 2021) emphasize the role of developing leadership skills in knowledge management and the direct realization of scientific potential. Functional education also plays an important role (Sułkowski et al., 2020), which is essential when training a quality workforce in conditions of correct interaction with the environment.

The popularization of the concept "Education 4.0", which is interpreted as the transformation of traditional education under the influence of information technologies into the environment of real and virtual worlds, has been studied in scientific articles by many scientists (Starčič & Lebeničnik, 2020; Caballero-Morales et al., 2020; Jiang et al., 2021; Gontareva et al., 2022). Based on the example of Latin American countries, they identify three key areas of entrepreneurship (small and medium-sized business, the sphere of social security and engineering), on which the activities of higher education institutions can be focused within the framework of the "Education 4.0" concept. Thus, scientists establish logical links between scientific activity and the national economy of countries. In one of the scientific publications (Exenberger & Bucko, 2020), one of the implementations of this concept is the development of special web interfaces for training special categories of people. Přívara & Kiner, 2020, in their study note that it is important to achieve the optimal level of specialists' qualifications and avoid overqualification, which can contribute to some educational environment deformation.

The information and communication technologies significantly affect the general economic growth of the country, in particular, the education sphere (Bauters et al., 2021; Cosmulese et al., 2019; Samusevych et al., 2021; Yarovenko et al., 2021; Shkarlet et al., 2019). Scientific works (Aljoghaiman al., 2022; Nezai et al., 2022) present a comparative analysis of the effectiveness of higher education institutions in the world's countries precisely in terms of the technology and knowledge development. Based on the results, the studied institutions obtained the competitiveness level, synchronized with international scientometric ratings. The correct formation of marketing guidelines also lays the foundation for healthy competition between educational institutions (Moreno-Carmona et al., 2022; Alam et al., 2019).

It is confirmed that the practice-oriented approach in organization of the higher school contributes to developing the entrepreneurial spirit and motivates students to get suitable jobs and find opportunities to implement their business ideas. It positively affects the country's national economy as a whole (Krisnaresanti, 2020; Vlasov et al., 2020; Abdimomynova et al., 2021). Undoubtedly, when opening own business, you may encounter many traditional obstacles, for example, capital limitations and the search for additional investments, business partners and lack of confidence in opening a new business, risks related to the competitors' activities in a particular business environment. However, all mentioned factors set the tone for readiness to be an active participant in the business environment (Serpeninova et al., 2020). It is important to understand the ability to adapt educational services to the requirements of the modern labor market (Delibasic et al., 2022; Zuluaga-Ortiz et al., 2022; Draskovic et al., 2020; Hitka et al., 2021). It is the best way to make a correlation between students' skills and their internship process. The work (Barrientos-Báez al., 2022) demonstrates the category "knowledge alliance", which arose based on the activities of EU higher education institutions in collaboration with various research and innovation centers. An arboretum can even be an example of a research center. It provides comprehensive opportunities for practical teaching (Kumar, et al., 2021; Mohanu et al., 2022; Kuzior et al., 2022a, 2022b; Midor et al., 2021; Polyakov et al., 2019, implement some key aspects of the activities of European higher education institutions in the domestic educational process (Polyakov et al., 2020).

The state financing of higher education institutions is complex and requires a comprehensive approach to forming its optimal volume. The question of a sufficient volume of necessary economic resources (Jankelová, 2022; Tsyhaniuk & Akenten, 2021; Volk et al., 2021) to form the basis of the modern educational process is particularly relevant today and needs to be solved since the resource redistribution to other fields depends on it. The role of public procurement is significant when allocating financial resources to the education sector (Wach & Bilan, 2021). The influence of the activities of financial institutions (Kozmenko & Vasyl'yeva, 2008; Obidjon et al., 2017), which take part in redirecting the necessary financial flows, cannot be rejected either. The concept of "autonomy" of higher education institutions is raised in the scientific community precisely in terms of financial support (Fadilah et al., 2021; Dzionek-Kozlowska, & Neneman, 2022). Using the example of higher education institutions in Lithuania, their ability to effectively respond to the socio-economic changes taking place in the country is examined. In addition to financial factors, the information security of the state also plays a significant role in forming the country's scientific potential (Novikov, 2021a, 2021b), etc.

2. Methodological approach

In this study, there are three groups of indicators, which respectively describe the quality of scientific activity (14 indicators), economic (11 indicators), and social development (8 indicators) of 35 European countries during 2014-2020.

The list of input indicators and their symbols is presented in *Tables 1-3*.

Table 1. List of indicators that characterize the quality of the countries' scientific activity

Symbol	Indicator	Units of measure
i1	Global innovation index	units
i2	Costs for research and development	percent of GDP
i3	Exports of information technology	percent of the total export of goods and services
i4	Exports of high-tech goods and services	million US dollars
i5	Exports of high-tech goods and services2	Percent of the total export of goods and services
i6	The country residents' patents	units
i7	Number of trademark applications (total number)	units
i8	The number of applications for trademarks of the country's residents	units
i9	The number of applications for trademarks of the country's non-residents	units
i10	The number of patents of the country's non-residents	units
i11	Number of articles in scientific and technical journals	units
i12	The amount of research and development costs	million US dollars
i13	Fee for using intellectual property objects (revenue)	US dollars
i14	Fee for using intellectual property objects (payments)	US dollars

Source: *World Bank, The Global Economy*

The first list included fourteen indicators characterizing the quality of scientific activity in the studied countries. This list is headed by the Global Innovation Index (GII) (i1), which

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since 2007 has been a key international indicator of the innovative development of all countries in the world.

The following indicators (i2, i12), Costs for research and development, show the volume of gross expenditure as a percent of GDP. These costs include capital and current expenditures in four major sectors: business enterprise, government, higher education, and private nonprofit organization. In terms of the research and development, fundamental and applied research, experimental development are considered.

The next indicator (i3), Exports of information technology, includes the following components: computers and peripheral equipment, communication equipment, consumer electronic equipment, electronic components and other information technology goods.

In contrast, the fourth and fifth indicators (i4, i5), Exports of high-tech goods and services, include products with a high intensity of research and development, such as the aerospace industry, computers, pharmaceuticals, scientific instruments and electric machines.

The sixth and tenth indicators (i6 and i10), Patents of residents and non-residents of the country, include worldwide patent applications filed under the procedure of the Patent Cooperation Treaty or to the national patent office for exclusive rights to an invention (a product or process that offers a new way of doing something or offers a new technical solution to a problem). In this case, we consider a patent that protects an invention to its owner for a limited period, usually 20 years.

The following three indicators (i7-i9) represent submitted trademark applications (trademark registration in national or regional intellectual property offices) and designations received by the relevant offices through the Madrid system, distributed according to their authors' residency.

The eleventh indicator (i11), Number of articles in scientific and technical journals, includes published works in the following areas: physics, biology, chemistry, mathematics, clinical medicine, biomedical research, engineering and technology, as well as earth and space sciences.

The last two indicators (i13, i14) represent payments and receipts between residents and non-residents for the authorized use of property rights (such as patents, trademarks, copyrights, industrial processes and designs, including trade secrets and franchises) and use through license agreements, created originals or prototypes (for example, copyrights in books and manuscripts, computer software, cinematographic works and sound recordings) and related rights (for example, in live performances and television, cable or satellite broadcasting).

The second list of input indicators contains eleven indices of the countries' economic development

Table 2. List of indicators that characterize the level of the coutries' economic development

Symbol	Indicator	Units of measure
e1	Import	US dollar
e2	Export	US dollar
e3	Trade openness	Percent of GDP
e4	Inflow of foreign direct investment	US dollar
e5	Inflow of net portfolio investments	US dollar
e6	Current account balance	Percent of GDP
e7	Current account balance2	US dollar
e8	Trade balance	Percent of GDP
e9	Foreign exchange reserves	US dollar
e10	GDP per capita	Thousand US dollar
e11	GNP growth	percent

Source: *World Bank, The Global Economy*

The first two indicators (e1, e2) characterize the level of export and import of goods and services.

The next indicator (e3), Trade openness, is defined as the ratio of the amount of exports and imports to the country's GDP

The fourth indicator (e4), Inflow of foreign direct investment, indicates net investment inflows for long-term management participation (10 percent or more of voting shares) in an enterprise operating in an economy that differs from the investor's country. It is the sum of equity capital, reinvested earnings, other long-term capital and short-term capital, as shown in the balance of payments.

The fifth indicator (e5), Net portfolio investment inflows, includes net inflows from equity securities except for those that are accounted for as direct investment, including stocks, shares, depositary receipts and direct purchases of shares on local stock markets by foreign investors.

The indicators (e6, e7) demonstrates the amount of net export of goods and services, net primary income and net secondary income.

The eighth indicator (e8), Trade balance, characterizes the difference between export and import of goods and services as a percentage of GDP.

Foreign exchange reserves (e9) consist of foreign currency, deposits denominated in foreign currency, monetary gold, special borrowing rights and a reserve position in the International Monetary Fund (IMF).

The last two indicators (e10, e11) reflect the total output per capita and the sum of the value added of all resident producers plus any taxes on products (net of subsidies) not included in the valuation of products, plus net receipts of primary income from abroad.

The last group of indicators consists of eight indicators that characterize the level of countries' social development.

Table 3. List of indicators that characterize the level of countries' social development

Symbol	Indicator	Units of measure
s1	Inflation	percentages
s2	Employers	percentage of employment
s3	Gini index	interest
s4	Age dependence	percentage of the working age population
s5	Compulsory education	years
s6	Current expenditure on education	percentage of total costs in public institutions
s7	Costs of final consumption	percent of GDP
s8	Unemployment rate	percentage of the total labor force

Source: *World Bank, The Global Economy*

The first indicator (s1) denotes inflation, which is measured as the annual growth rate of the implicit GDP deflator, and shows the speed of price changes in the economy as a whole.

The next indicator (s2), Employers, represents those workers who, working for themselves or with one or more partners, are "self-employed", i.e., their remuneration directly depends on the profit obtained from goods and services.

The Gini index (s3) measures the degree to which the distribution of income or consumption among individuals or households in an economy deviates from a perfectly equal distribution (0 means complete equality, 100 - complete inequality).

The fourth indicator (s4), Age dependency, denotes the age dependency ratio (the ratio of persons younger than 15 years and older than 64 years to the working-age population aged 15-64 years).

The fifth indicator (s5) shows the officially approved duration of compulsory education in the years during which children must attend school.

The next indicator (s6), Current expenditure on education, is a percentage of direct expenditure in public educational institutions of the indicated level of education.

Expenditure on final consumption (s7) is the sum of costs on the final consumption of households and the final consumption of the state budget.

The unemployment rate (s8) shows the share of the labor force that is currently unemployed but is ready and looking for it.

We will test the hypothesis regarding the impact of the scientific activity quality and the dynamics of the innovative processes on socio-economic development of the country's national economy using structural modeling. Structural modeling is one of the methods of performing economic-mathematical modeling, which identifies hidden (latent) links between the studied structural elements.

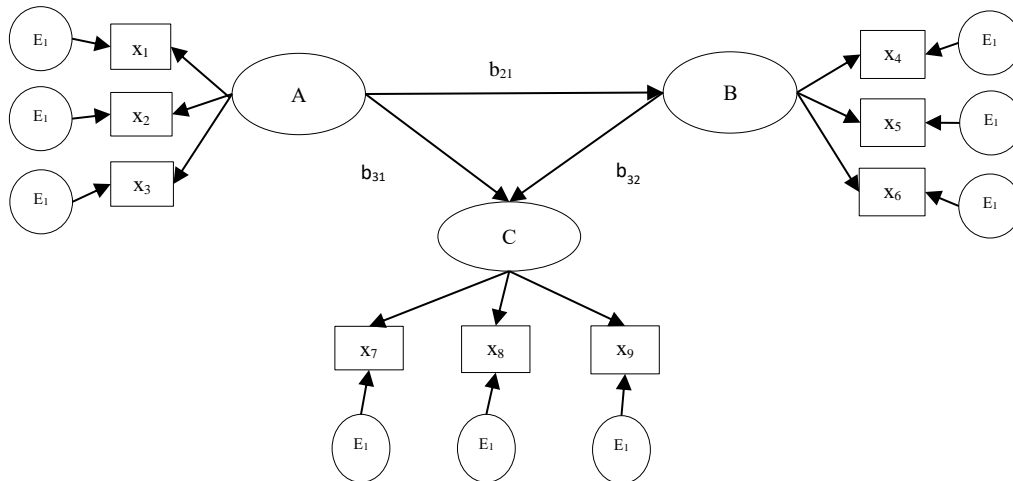A graphic representation of the general structural model is presented in Fig. 1.

Figure 1. Graphic representation of the general structural model, where latent variables are located in ovals; explicit variables - in rectangles; residual - components in circles
Source: *own data*

While testing the determined hypothesis of the research, it is necessary to introduce symbols of latent indicators. Three latent variables are proposed:

−   *INNOV* – a latent variable identifying the scientific activity of the studied countries;

−   *ECON* – a latent variable identifying the economic level of countries' development;

−   *SOC* – a latent variable identifying the level of countries' social development.

The graphic representation of functional dependencies between these latent variables is shown in Fig. 2.
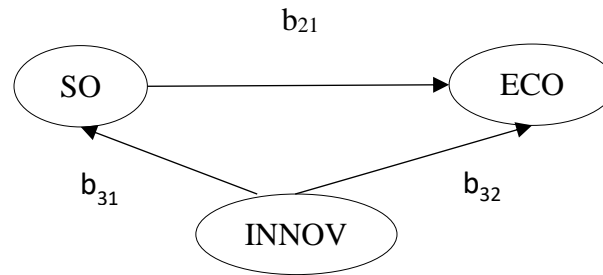
Figure 2. Graphic representation of functional dependencies between latent variables
Source: *own data*

It is necessary to use the principal component method to select an array of relevant indicators for each latent variable.

In addition, the research also includes clustering of the studied countries based on two methods: the k-means method and hierarchical clustering (Word's method).

3. Conducting research and results

As a result of using the principal component method, indicators with factor loading greater than 0.7 were selected. For optimal construction of the structural model, it is necessary to choose five indicators from each studied group. In our case, this condition is met by the following indicators that characterize the quality of countries' scientific activity: Export of goods and services in the field of high technologies (i4), Number of articles in scientific and technical journals (i11), Number of residents' patents (i6), Number of applications for trademarks (total number) (i7) and Fees for the use of intellectual property objects (income) (i13). Thus, in structural modeling, the latent variable *INNOV* is conditioned by these five indicators.

Similarly to the presented algorithm for selecting relevant indicators, it is necessary to filter the following two groups.

The five indicators of the research group, which will be used to identify the *ECON* latent variable, have the following form (factor loading greater than 0.7): Export (e2); Import (e1); Trade balance (e8); Trade openness (e3) and Inflow of net portfolio investments (e5).

According to the obtained results, the five indicators of the research group, with the help of which the *SOC* latent variable will be identified, have the following form (factor loading greater than 0.7): Employers (s2), Final consumption costs (s7), Unemployment rate (s8), Inflation (s1) and Age dependence (s4).

As a result of the principal components method, fifteen variables which provide the corresponding latent variables were identified. The supplemented schematic representation of the relationships between all variables is as follows (Fig. 3).
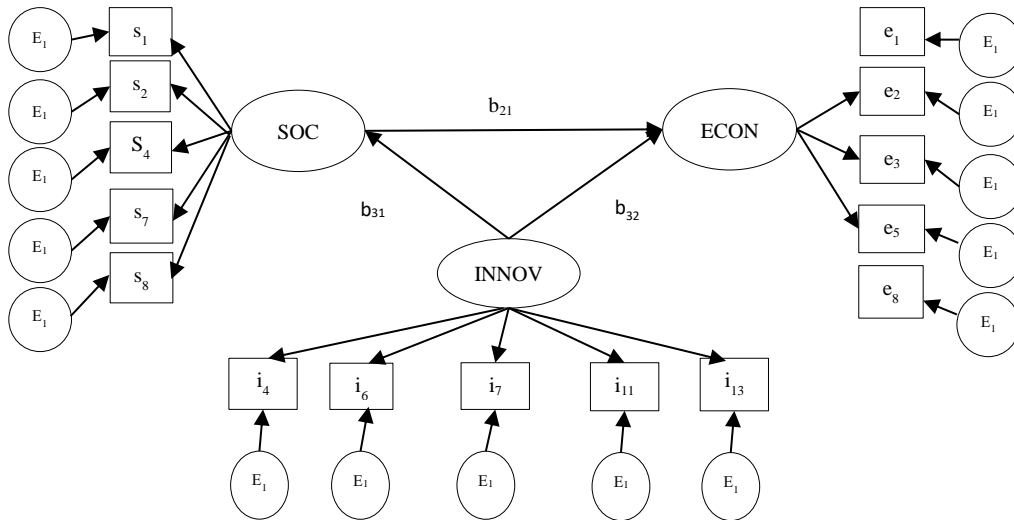
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Figure 3. Schematic representation of links between latent and manifest variables
Source: *own data*

The obtained parameters and other effective indicators of structural modeling are presented in Fig. 4.

	Parameter	St. error	T	p-value
(INNOV)-1->[i4]	0,498	0,060	8,247	0,000
(INNOV)-2->[i11]	0,498	0,060	8,247	0,000
(INNOV)-3->[i6]	0,498	0,060	8,247	0,000
(INNOV)-4->[i7]	0,498	0,060	8,247	0,000
(INNOV)-5->[i13]	0,800	2,867	0,279	0,780
(DELTA1)-->[i4]				
(DELTA2)-->[i11]				
(DELTA3)-->[i6]				
(DELTA4)-->[i7]				
(DELTA5)-->[i13]				
(DELTA1)-6-(DELTA1)	0,500	0,056	8,928	0,000
(DELTA2)-7-(DELTA2)	0,500	0,056	8,928	0,000
(DELTA3)-8-(DELTA3)	0,500	0,056	8,928	0,000
(DELTA4)-9-(DELTA4)	0,500	0,056	8,928	0,000
(DELTA5)-10-(DELTA5)	1456,699	131,905	11,044	0,000
(ECON)-->[e2]				
(ECON)-11->[e1]	11,098	94,962	0,117	0,907
(ECON)-12->[e8]	0,454	0,090	5,052	0,000
(ECON)-13->[e3]	0,454	0,000		
(ECON)-14->[e5]	0,381	29,258	0,013	0,990
(SOC)-->[c2]				
(SOC)-15->[c7]	0,500	0,052	9,632	0,000
(SOC)-16->[c8]	0,500	0,052	9,632	0,000
(SOC)-17->[c1]	0,500	0,052	9,632	0,000
(SOC)-18->[c4]	0,500	0,051	9,802	0,000
(EPSILON1)-->[e2]				

	Parameter	St. error	T	p-value
(EPSILON2)-->[e1]				
(EPSILON3)-->[e8]				
(EPSILON4)-->[e3]				
(EPSILON5)-->[e5]				
(EPSILON6)-->[c2]				
(EPSILON7)-->[c7]				
(EPSILON8)-->[c8]				
(EPSILON9)-->[c1]				
(EPSILON10)-->[c4]				
(EPSILON1)-19-(EPSILON1)	1339124,131	121238,637	11,045	0,000
(EPSILON2)-20-(EPSILON2)	1090460,748	98733,440	11,044	0,000
(EPSILON3)-21-(EPSILON3)	0,500	0,066	7,533	0,000
(EPSILON4)-22-(EPSILON4)	0,500	0,000		
(EPSILON5)-23-(EPSILON5)	103528,581	9373,046	11,045	0,000
(EPSILON6)-24-(EPSILON6)	0,500	0,000		
(EPSILON7)-25-(EPSILON7)	0,500	0,051	9,820	0,000
(EPSILON8)-26-(EPSILON8)	0,500	0,051	9,820	0,000
(EPSILON9)-27-(EPSILON9)	0,500	0,051	9,820	0,000
(EPSILON10)-28-(EPSILON10)	0,500	0,000		
(ZETA1)-->(ECON)				
(ZETA2)-->(SOC)				
(ZETA1)-29-(ZETA1)	0,635	0,000		
(ZETA2)-30-(ZETA2)	0,511	0,107	4,760	0,000
(INNOV)-31->(ECON)	0,501	0,123	4,064	0,000
(INNOV)-32->(SOC)	0,530	0,119	4,469	0,000
(ECON)-33->(SOC)	0,420	0,149	2,825	0,005

Figure 4. Results of structural modeling
Source: *own data*

Given the obtained results, one should note that all calculated modeling parameters are statistically significant since the probability level p is less than 0.05. Besides, to assess the quality of building a structural model, there are such criteria (Table 4).

Table 4. List of indicators that characterize the level of countries' social development

Criterion	Criterion value
Maximum Residual Cosine	0,388
ML Chi-Square	158,804
ICSF Criterion	1,818
ICS Criterion	0,858
P-level	0,000
RMS Standardized Residual	0,032

Source: *own calculation*

As can be seen from Table, the Maximum Residual Cosine goes to 0, which indicates that the iterative process was successful. The values of ICSF Criterion and ICS Criterion are close to 0, which indicates that the built model is resistant to multiplication by a constant scaling factor and to scale changes.

Since the p-level for the Chi-square statistic is less than 0,05, we reject the null hypothesis at a significance level of 0,95. The RMS index evaluates the quality of model fit. In a situation where the index is less than 0.05, the simulation results are qualitative. In this case, the calculated maximum cosine of the residuals is 1, and the RMS index is 0.032, which confirms the adequate obtained results.

We put the obtained modeling parameters (Fig. 4) into the system of structural equations (1) and get the following results (1).

$$\begin{cases} ECON = 0.501 INNOV + 0.635, \\ SOC = 0.530 INNOV + 0.420 ECON + 0.511. \end{cases} \tag{1}$$

We can see that the latent variable $INNOV$ exerts a statistically significant direct influence on both dependent variables $ECON$ and SOC. Moreover, the effect on the variable indicating the countries' social development is stronger since the obtained modeling parameter is equal to 0.530, unlike the parameter near the latent variable of the countries' economic development. Thus, the quality of scientific activity and the dynamics of the innovative development in the country directly depend on its socio-economic development, confirming the proposed hypothesis.

Since the studied sample included 35 European countries, which differ in socio-economic development, we check how much their redistribution has changed in the context of scientific and innovative transformations in 2020 compared to 2014. We will carry out clustering of countries using two methods: the *k*-means method and hierarchical clustering, based on five indicators selected by the principal component method, which characterize the quality of scientific and innovative activity of countries: Exports of high-tech goods and services (i4), Number of articles in scientific and technical journals (i11), The country residents' patents (i6), Number of trademark applications (total number) (i7) and Fees for the use of intellectual property objects (income) (i13). Before proceeding to the construction of clusters, the input data must be standardized, since they are measured in different quantities. For this, we will use the standard deviation and the average value.

Using hierarchical clustering (Word's method), four key clusters were identified among the studied countries in 2014, presented on the horizontal dendrogram (Fig. 5).
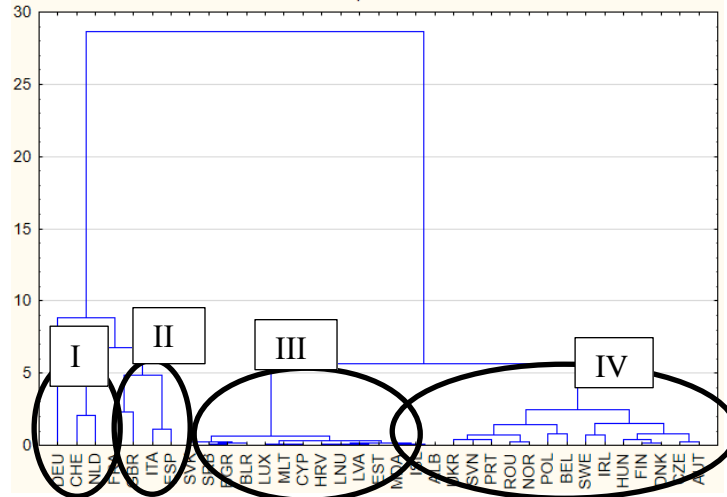
Figure 5. Dendrogram of the studied European countries clustering in 2014 via Word's method
Source: *own data*

The second method of clustering, the *k*-means method, will allow us to detail the composition of the constructed clusters and the influence of each indicator.

Since the construction of these clusters is based on five criteria, it is necessary to determine which of them exerts the greatest influence during the grouping of countries. Variance analysis allows this check to be carried out (Table 5).

Table 5. Results of variance analysis (2014)

Indicators	Criteria			
	Intergroup variance	Intragroup variance	*F*-criterion	*p*-level
i4	26,775	7,225	59,292	0,000
i6	22,830	11,170	32,701	0,000
i7	22,890	11,110	32,963	0,000
i11	23,669	10,331	36,658	0,000
i13	30,305	3,695	131,227	0,000

Source: *own data*

Since the *p*-level of all indicators from the table 11 is less than 0.05, which means that all indicators play a significant role in the clustering of countries. Given that the *p*-level of the Exports of high-tech goods and services (i4) and Fees for the use of intellectual property objects (income) (i13) is the smallest, we can talk about the priority of these indicators. The qualitative composition of clusters as of 2014 is as follows (Table 6)

Table 6. The composition of the received clusters as of 2014

Cluster 1	Cluster 2	Cluster 3	Cluster 4
NLD, DEU, GBR, CHE	FRA, SWE	BEL, DNK, IRL, ITA, HUN, FIN	AUT, ALB, BLR, BGR, EST, ISL, ESP, CYP, LVA, LTU, LUX, MLT, MDA, NOR, POL, PRT, ROU, SRB, SVK, SVN, UKR, HRV, CZE

Source: *own data*

The analysis of the average values of the criteria shows that the leading countries represent the first cluster in terms of five indicators that characterize the quality of scientific and innovative activity; the second, respectively, consists of countries with lower values of the corresponding indicators; the third and fourth have close average values of the investigated indicators.

We will group countries according to five indicators as of 2020 in the same way. We present a dendrogram based on hierarchical clustering (Word's method) (Fig. 6).

As we can see, in 2020, the countries are also redistributed to a greater extent into four clusters. However, it becomes noticeable that the composition of the clusters is somewhat different from what it was in 2020. The *k*-means clustering method will reveal this difference. First, we will conduct a dispersion analysis to verify the qualitative effect of the indicators that underlie the clustering process (Table 7).

The variance analysis results confirm the effect made by all indicators and, in particular, the effect of i4 and i13.
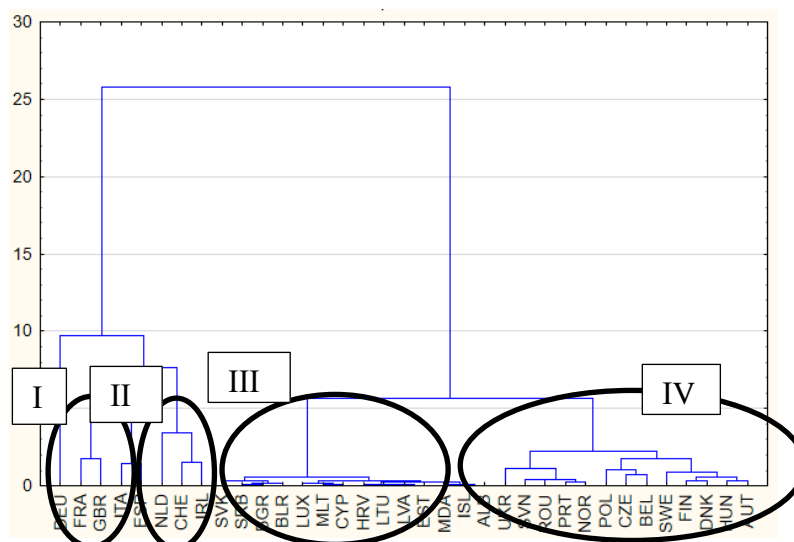

Figure 6. Dendrogram of the clustering of the studied European countries in 2020 through Word's method
Source: *own data*

Table 7. Results of variance analysis (2020)

Indicators	Criteria			
	Intergroup variance	Intragroup variance	*F*-criterion	*p*-level
i4	22,267	11,733	30,366	0,000
i6	22,296	11,704	30,480	0,000
i7	28,541	5,459	83,646	0,000
i11	28,932	5,068	91,344	0,000
i13	19,468	14,532	21,434	0,000

Source: *own data*

The qualitative composition of clusters as of 2020 is shown in Table 8.

Table 8. Composition of the received clusters as of 2020

Cluster 1	Cluster 2	Cluster 3	Cluster 4
NLD, DEU	IRL, GBR, FRA, CHE	BEL, DNK, ESP, ITA, FIN, SWE	AUT, ALB, BLR, BGR, EST, ISL, ESP, CYP, LVA, LTU, LUX, MLT, MDA, NOR, POL, PRT, ROU, SRB, SVK, SVN, UKR, HRV, CZE

Source: *own data*

Average values of factor indicators for selected clusters as of 2020 have the following form (Fig. 12). Similarly to the clusters of 2014, the redistribution of average values repeats the trend in which the first cluster includes countries with the highest values of factor characteristics, and the fourth - with the lowest.

Conclusion

Thus, according to the goal of the research, i.e., to identify functional links between key indicators of scientific activity and socio-economic development of the national economy, and verify the hypothesis that the quality of scientific activity and the dynamics of the innovative development are the key determinants of socio-economic development of the country's national economy, it was determined that scientific activity exerts a statistically significant direct impact on the country's socio-economic development. Moreover, the influence on the variable denoting the social development of countries is stronger since the obtained modeling parameter is equal to 0.530, unlike the parameter near the latent variable of countries' economic growth. Thus, the quality of scientific activity and the dynamics of the innovative development in the country directly depends on its socio-economic development, which allows us to confirm the proposed hypothesis.

Besides, the clustering of the studied countries made it possible to identify some transformations. In 2020, Great Britain and Switzerland left the cluster, which included countries with a high scientific and innovative activity, moving to the second cluster. It happened due to the reduction of three out of five indicators. As for the indicators of Great Britain, there are following negative changes: Exports of high-tech goods and services (i4) decreased by 23.5% as of 2020; The country residents' patents (i6) - by 21%; The number of articles in scientific and technical journals (i11) - by 0.35%. At the same time, The number of trademark applications (total number) (i7) increased in 2020 compared to 2014 by 41.2%, and the Fee for the use of intellectual property objects (income) (i13) - by 17.4% .

As for Switzerland, we have the following picture: as of 2020, Exports of high-tech goods and services (i4) decreased by more than 48%; The country residents' patents (i6) - by 6.5%; The number of articles in scientific and technical journals (i11) - by 0.86%. At the same time, the Number of trademark applications (total number) (i7) increased in 2020 compared to 2014 by 6.36%, and the Fee for the use of intellectual property objects (income) (i13) - by 0.14% .

Sweden also showed negative trends in 2020 compared to 2014, moving from the second cluster to the third. This situation is caused by the decrease of four indicators at once: Exports of high-tech goods and services (i4) as of 2020 by 16.8%; The country residents' patents (i6) - by 11.1%; The number of articles in scientific and technical journals (i11) – by 1.5%, and Fees for the use of intellectual property objects (income) (i13) – by more than 10%.

Positive shifts in scientific activity in 2020 are observed in Ireland. This country demonstrated an increase in almost all studied indicators by several times, except for the Number of articles in scientific and technical journals (i11), which as of 2020 decreased by more than 1.68 %. As a result of such positive changes, Ireland moved from the third to the second cluster. Having moved from the fourth cluster to the third. Spain demonstrated positive dynamics of changes in three out of five indicators: Exports of high-tech goods and services (i4); Number of trademark applications (total number) (i7), and Fees for the use of intellectual property objects (income) (i13).

Thus, it was found that all countries were divided into four clusters, the qualitative structure of which is determined by the absolute value of the indicators underlying the clustering. Not all countries with a high economic development fell into the first cluster, which accumulated countries with the highest indicators of scientific and innovative activity. It gives reason to conclude about the asymmetry between the economic development of the country and its scientific potential.

Acknowledgement

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