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THE TRIAD «EDUCATION-SCIENCE-INNOVATION»: INDICATORS AND CHALLENGES FOR BELARUS[1]

Objective *– to analyze the trends in the development of higher education in the context of its interaction with scientific-innovation activity, as well as in the identification of regularities and stable relations of the triad "education-science-innovation" in the context of their impact on the economic security of the country.*
Materials and methods. *The study was carried out on the basis of statistical data characterizing the spheres of «education» and «science and innovation». General (analysis, observation, measurement, comparison) and special (statistical-economic, data visualization) methods of scientific research were applied.*
Results. *The article analyzes the dynamics of specific indicators characterizing the innovation potential of education and science for the period 2016-2023, studies the performance of innovation activity of the national economy. It is concluded that the identified negative trends (decrease in the share of the higher education sector in R&D, low share of education expenditures in the total amount of budget expenditures, decrease in the share of persons who graduated from postgraduate education with the defense of a thesis for the degree of candidate or doctor of sciences, steady decrease in the number of students in the total population, decrease in the inventive and patent activity of national applicants) can significantly limit the potential of the education system in the field of innovation and scientific development of the national economy. It is stated that the establishment of patterns that determine the successful interaction between education, science and innovation will allow to create a model that promotes a more effective exchange of knowledge and resources.*
Conclusion. *The research is aimed at creating an effective strategy of interaction between education, science and innovation, which will have a positive impact on innovation activity and, ultimately, will contribute to sustainable economic growth and increase the competitiveness of the country. Thus, the results of the study will allow not only to identify sustainable interrelationships in the triad "education-science-innovation", but also to develop practical recommendations that will help to create a harmonious ecosystem for innovative development.*

Keywords: *innovation, education, scientific activity, economic competitiveness, innovation policy.*

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ТРИАДА «ОБРАЗОВАНИЕ-НАУКА-ИННОВАЦИИ»: ИНДИКАТОРЫ И ВЫЗОВЫ ДЛЯ БЕЛАРУСИ

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Цель исследования *– анализ тенденций развития сферы высшего образования в контексте его взаимодействия с научно-инновационной деятельностью, а также в выявлении закономерностей и устойчивых связей триады «образование-наука-инновации» в контексте их влияния на экономическую безопасность страны.*

Материалы и методы. *Исследование проведено на основе статистических данных, характеризующих отрасли «образование», «наука и инновации». Применены общие (анализ, наблюдение, измерение, сопоставление) и специальные (статистико-экономический, визуализация данных) методы научного исследования.*

Результаты. *В статье проанализирована динамика отдельных показателей, характеризующих инновационный потенциал образования и науки за период 2016-2023 года, изучена результативность инновационной деятельности национальной экономики. Сделан вывод о том, что выявленные негативные тенденции (снижение доли сектора высшего образования в НИОКР, низкий удельный вес расходов на образование в общей сумме расходов бюджета, сокращение доли лиц, окончивших последипломного образования с защитой диссертации на соискание степени кандидата или доктора наук, устойчивое снижение числа студентов в общей численности населения, снижение изобретательской и патентной активности национальных заявителей) могут существенно ограничить потенциал системы образования в области инноваций и научного развития. Определено, что установление закономерностей, которые определяют успешное взаимодействие между образованием, наукой и инновациями, позволит создать модель, способствующую более эффективному обмену знаниями и ресурсами.*

Заключение. *Исследование направлено на создание эффективной стратегии взаимодействия образования, науки и инноваций, что положительно скажется на инновационной активности и, в конечном итоге, будет способствовать устойчивому экономическому росту и повышению конкурентоспособности страны.Таким образом, результаты исследования позволят не только выявить устойчивые взаимосвязи в триаде «образование-наука-инновации», но и разработать практические рекомендации, которые помогут создать гармоничную экосистему для инновационного развития.*

Ключевые слова: *инновации, образование, научная деятельность, конкурентоспособность экономики, инновационная политика.*

Introduction. The transition of the national economy to the post-industrial stage of development, the increasing role of human and, in particular, intellectual capital, innovation activity of all subjects of the market economy requires a re-evaluation of both the process of educational activity itself and the interaction, or, more precisely, the merger of the sphere of education, science and innovation. Science can no longer be perceived as an elitist and isolated from mass education.

Scientific research should be integrated into the educational process, starting from the first years of higher education. Only in this case it is possible to form the necessary critical mass of educated and research-minded specialists, who will be receptive to innovations and will have the necessary competencies for their implementation.

The role of interaction within the triad “education-science-innovation” is manifested in the following:

– research-based innovation can become a powerful driver of economic development, with quality education providing people with skills that meet the requirements of the modern market;

– research can have an impact on pressing social issues such as health, environment and technology, while education helps people to become more knowledgeable and engaged in these processes;

– countries that actively develop this triad become more globally competitive, as investment in science and education provides technological leadership and sustainable development;

– creating sustainable links between educational institutions, research centers and businesses fosters an ecosystem where ideas can be quickly transformed into practical solutions that contribute to the development of new technologies and services.

These aspects emphasize the importance of the triad “education-science-innovation” for the

state and society as a whole, creating a foundation for future progress.

The relevance of the research topic for the national economy is confirmed by the provisions fixed in the documents of strategic development of the Republic of Belarus: the National Strategy of Sustainable Socio-Economic Development of the Republic of Belarus for the period until 2035 [1], the Program of Socio-Economic Development of the Republic of Belarus for 2021-2025 [2], the State Program «Of Innovative Development of the Republic of Belarus for 2021-2025» [3], the State Program «Science-intensive Technologies and Engineering for 2021-2025» [4].

Main part. Proceeding from the thesis that the key factor in ensuring economic security of the national economy is innovation, we study the innovation component of the triad "education-science-innovation" as applied to the economy of the Republic of Belarus [5].

The Global Innovation Index (GII), published by World Intellectual Property Organization (WIPO) together with Cornell University and The Business School for The World INSEAD [6], is a comprehensive indicator characterizing the state of the innovation sphere. It is an important tool for assessing the innovation potential and performance of countries around the world.

The use of GII as a key indicator is justified by the fact that it:

– measures the innovative capacity and results of innovative development of most countries in the world (more than 130 countries are evaluated);

– allows comparing countries by the level of innovative development, as standardized indicators are used for assessment (more than 80 indicators are used and development institutions, human capital, innovation infrastructure, level of business development, scientific results, creativity of national researchers and results of creative activity are assessed);

– is a universal analytical tool as it provides detailed statistics on innovation ecosystems and helps to identify the strengths and weaknesses of countries' innovation policies;

– stimulates the development of countries by motivating governments to improve the conditions for innovation, and promotes a transparent competitive environment for technological development.

The index helps countries understand their innovation potential and design development strategies. The position of the Republic of Belarus in the GII is presented in table 1.

The position of the Republic of Belarus in the Global Innovation Index (GII) shows a downward trend, which raises certain concerns about the country's innovation activity and competitiveness in international markets. A particularly sharp drop is observed in 2022 and 2024, which can be attributed to various internal and external economic reasons, including changes in the educational and scientific environment, economic sanctions and other challenges.

Interestingly, while the country's overall index position is deteriorating, the rate of decline in terms of practical innovation performance remains moderate. This may indicate that there are still some achievements in innovation and certain sectors continue to develop despite the overall negative trends.

However, the most worrying factor is the drop in the indicators of access to resources and conditions for innovation activities. This can be attributed to funding constraints, low levels of investment in R&D, and a decline in the number of innovation-oriented personnel and firms.

To better understand the challenges of innovation development, let us compare the position of the Belarusian economy with that of its closest partner countries, members of the Eurasian Economic Union (table 2).

Table 1. – The Republic of Belarus in the Global Innovation Index

Year	Gill position	Innovation Inputs	Innovation Outputs
2020	64	67	61
2021	62	68	62
2022	77	86	63
2023	80	88	66
2024	85	102	69

Source: [6]

Table 2. – Members of the Eurasian Economic Union in GII in 2024

Indicators	Belarus	Kyrgyzstan	Kazakhstan	Armenia	Russia
Gill position	85	99	78	63	59
Innovation Inputs	*102*	*79*	*72*	*86*	*76*
1. Institutions	132	119	75	77	126
2. Human capital and research	43	42	65	89	36
3. Infrastructure	87	78	68	79	76
4. Market sophistication	98	81	86	83	57
5. Business sophistication	81	117	66	85	53
Innovation Outputs	*69*	*55*	*83*	*105*	*56*
6. Knowledge and technology outputs	46	107	85	60	52
7. Creative outputs	92	104	83	46	53

Source: [6]

Comparing the data on Belarus' partner countries, it can be noted that the resource indicators in all countries of the Eurasian Economic Union are significantly higher than in the Republic of Belarus. At the same time, in terms of innovation performance in general, Belarus is behind only Russia and Kyrgyzstan, while in terms of knowledge economy development Belarus is ahead of its EEU partners. Thus, Belarus produces more innovative products relative to the level of investment in innovation. In order to find out the reasons for this state of the innovation environment, it is useful to analyze the national education and science indicators.

First of all, let us consider the financing of innovations in the industrial sector and analyze the activity of enterprises in terms of expenditures on innovation activities (fig.).

As follows from Figure, the share of industrial enterprises that spend on innovation is steadily growing throughout the analyzed period. At the same time, starting from 2020, the growth rate has slowed down significantly. Meanwhile, it should be noted that the share of such organizations remains insufficiently high and amounts to less than 30% of the total number of economic entities.

The quantitative indicator of innovation costs does not have a stable trend: while there was growth until 2020, the most significant in 2017, by 2022 the volume of investment costs sharply decreased and practically returned to the initial level, and taking into account inflation we can talk about the "point of minimum innovation costs" in 2022.

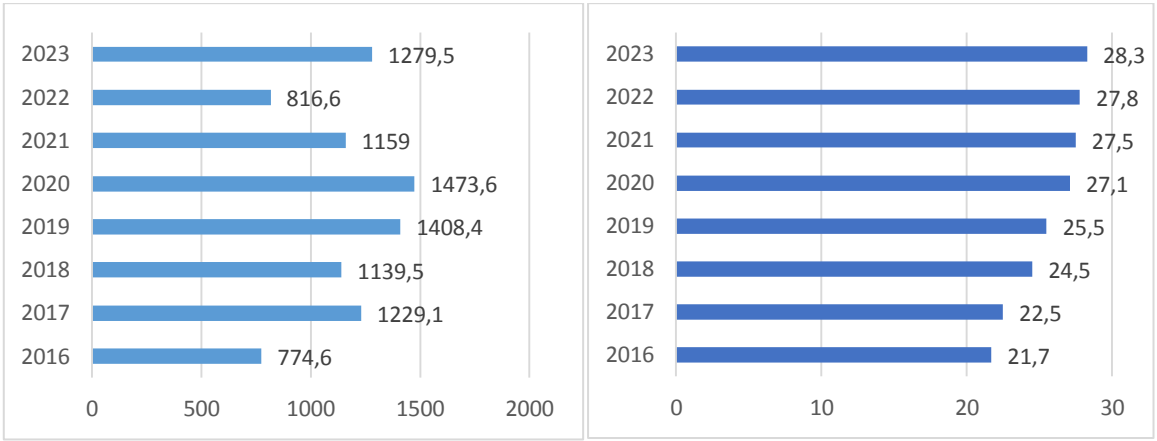

Figure - Indicators characterizing investment in innovation in industry in the Republic of Belarus in 2016-2023

[1]innovation expenditures of industrial organizations in current prices in the Republic of Belarus as a whole in 2019-2023, million rubles

[2] share of industrial organizations that incurred innovation costs in the total number of surveyed industrial organizations in the Republic of Belarus, per cent

Source: [7]

Assessing the economic environment (according to the EIS-2023 data) we note that in the whole country the share of organizations making expenditures on innovation is even lower and amounts to only 20.4% (the peak was reached in 2019 - 21.1%) [7].

Another problematic aspect from the position of resource potential is the low level of innovation activity of small and medium-sized enterprises (participating in joint innovation projects), the share of which is only 0.68% in 2023 and this is the most significant indicator since 2016 [7]. Innovation activity is determined not only by the financing of innovation, the level of financing and scientific potential of the country are also important. The indicators characterizing the "science" sector are presented in table 3.

In the dynamics of the indicators presented in Table 3, a certain regularity can be noted: most of them had an upward trend up to 2020, and then the trend reversed. This is not only a factor that negatively affected the country's position in the GII, but also laid down negative trends for the future, as the reduction of the innovative potential of science inevitably leads to a decline in innovation activity in all spheres of the national economy.

At the same time, there are indicators, the negative trend of development of which is still in place. For example, the share of budget financing of domestic R&D expenditures is falling, and the inventive and patent activity of national applicants is decreasing.

It is important to analyze the innovation potential of science in relation to the development of the "education" sector, since education and science interact to train qualified personnel who can both create new knowledge and put it into practice. Innovations appear at the intersection of theory and practice, which enhances the effectiveness of the educational process. Specific indicators of the "education" sector characterizing its innovation potential are presented in table 4.

Negative trends in the development of innovation capacity in education are manifested as follows:

– decrease in the share of the higher education sector in R&D: In 2023, this indicator amounted to only 9.3%, which is the worst value for the entire period under study. This indicates a declining interest in research within higher education institutions;

Table 3. – Specific indicators characterizing the innovation potential of science in 2016-2023.

Indicators	2016	2017	2018	2019	2020	2021	2022	2023
Share of R&D expenditures in GDP, per cent	0,50	0,58	0,60	0,59	0,54	0,46	0,47	0,58
including the share of public sector expenditures	*0,17*	*0,19*	*0,19*	*0,20*	*0,20*	*0,16*	*0,17*	*0,18*
Number of researchers per 1 million inhabitants	1776	1799	1877	1897	1477	1439	1430	1499
Number of organizations performing R&D, units	431	454	455	460	451	445	448	462
Listed number of employees performing scientific research and development, persons	25942	26483	27411	27735	25622	25644	25233	26738
of them have an academic degree doctor of sciences	631	646	627	608	560	550	523	519
PhD	2841	2884	2864	2833	2760	2659	2603	2724
Number of applications for inventions received, units	521	524	547	393	394	386	342	359
Including - domestic applicants	455	434	454	298	317	276	279	286
- foreign applicants	66	90	93	95	77	110	63	73
Inventive activity rate	0,5	0,5	0,5	0,4	0,4	0,4	0,4	0,4
Share of budget financing of domestic R&D expenditures, per cent	44,0	41,8	40,8	44,2	44,5	41,9	43,1	42,0
Share of employment in science-intensive activities, per cent	32,26	35,26	35,41	36,04	36,35	35,22	35,29	35,47

Source: [7], [8]

Table 4. – Specific indicators, characterizing the scientific and innovation potential of education in 2016-2023

Indicators	2016	2017	2018	2019	2020	2021	2022	2023
Share of higher education sector in domestic R&D expenditure, per cent	9,6	9,4	9,6	10,1	10,0	10,1	11,0	9,3
Share of education expenditures in total budget expenditures, percent[1]	13,6	13,0	13,3	13,1	12,9	12,4	12,8	…[3]
Public expenditure on education, as a percentage of GDP1	4,9	4,8	5,4	5,0	4,9	4,6	4,6	5,0
The share of postgraduates with a thesis defense in the total number of postgraduate students, per cent	7,1	9,1	10,7	10,2	8,4	6,3	8,4	5,7
The share of persons who graduated from doctoral studies with thesis defense in the total graduation from doctoral studies, per cent	7,5	26,7	8,7	13,8	13,5	8,3	10,7	6,7
The share of population aged 25-34 with completed higher education, per cent	29,8[2]	29,8[2]	29,8[2]	29,8[2]	40,8	40,8	40,8	40,8
Number of students per 10,000 people	343	317	300	290	282	276	259	254
Graduation rate of specialists with a higher education diploma from higher education institutions of the Republic of Belarus, per cent	...[3]	…[3]	…[3]	65,8	63,7	63,5	63,9	53,7

Notes –

[1] according to the World Bank: open data. Access mode: https://data.worldbank.org/indicator/SE.XPD.TOTL.GB.ZS?locations=BY

[2] according to 2009 census data

[3] … no data

Source: [7], [9]

– the share of education expenditures in total budget expenditures has also fallen to a critical minimum of less than 13%. which jeopardizes the quality and accessibility of education;

– the share of persons who graduated from postgraduate and doctoral programs with thesis defense in the total output at the level of postgraduate education has also reached a critical minimum -.5.7% in postgraduate programs and 6.7% in doctoral programs in 2023, these figures indicate a serious problem with the training of scientific personnel;

– the number of students per 10 thousand people continues to decline steadily, and in 2023 this figure is 254, which corresponds to the level of the 1990s. This indicates that the education system does not attract a sufficient number of students who could later become innovation-active specialists.

These negative trends may significantly limit the potential of the education system for innovation and scientific development.

The data in Table 5 indicate positive dynamics of the actual results of innovation activity, which is largely explained by the existence of a time gap between investments in the resource component and their return. This means that the positive trends observed in the period from 2016 to 2020 contributed to an increase in the qualitative indicators characterizing innovation performance in the following years.

Data from the Global Innovation Index (GII) also confirm this: the practical results of innovation implementation were significantly higher than the resources spent in the period from 2022 to 2024.

Consequently, it is necessary to overcome the negative trends in the resource component of innovation after 2020. This could increase the efficiency of innovation in the country and strengthen the position of Belarus in the Global Innovation Index.

Conclusion. Thus, the analysis suggests that Belarus shows positive results in certain aspects of economic and innovation development compared to other neighboring countries.

Table 5. – Specific indicators, characterizing innovation efficiency in 2016-2023

Indicators	2016	2017	2018	2019	2020	2021	2022	2023
Share of shipped innovative products in the total volume of shipments of industrial enterprises, per cent	16,3	17,4	18,6	16,6	17,9	19,8	17,7	22,2
Structure of shipped innovative products: - share of new products for the domestic market	43,5	49,1	55,2	45,2	48,2	52,8	49,0	55,8
- share of new products for the world market	0,5	0,5	1,2	1,6	0,5	0,6	0,6	0,8
Share of exports of science-intensive services in total exports of services, per cent	34,9	36,9	42,6	47,5	52,3	54,6	49,7	48,5

Source: [7]

The elimination of existing imbalances and a more efficient use of available resources and competencies can contribute to the country's further development. The Global Innovation Index can serve as a tool for diagnosing innovation potential, identifying areas for improvement in the innovation environment and developing public innovation policies. Its indicators are not only used in international comparisons, but are also used to assess the effectiveness of the national innovation ecosystem.

Innovations resulting from scientific research can indeed become a key driver of economic growth. Quality education plays a crucial role in this process, providing people with the necessary skills to meet the demands of today's labor market. Scientific research not only contributes to the creation of new technologies, but also helps to tackle pressing social issues such as sustainable development.

In addition, education raises awareness and engagement of citizens in processes related to scientific advances and innovation, which is important for creating an active and informed society. Establishing strong links between educational institutions, research centers and businesses helps to create an innovation ecosystem where ideas can be quickly transformed into practical solutions. This, in turn, stimulates the development of new technologies and services, which is highly relevant in a rapidly changing global economy.

Thus, the realization of the integration of education, science and business creates conditions for improving the competitiveness and sustainable development of both individual regions and the country as a whole.

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