"Knowledge creation, knowledge impact and knowledge diffusion: how do they connect with higher education?"

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KNOWLEDGE CREATION, KNOWLEDGE IMPACT AND KNOWLEDGE DIFFUSION: HOW DO THEY CONNECT WITH HIGHER EDUCATION?

Abstract

Knowledge-based economy causes changes in the higher education system: university graduates must have the ability to constantly learn and improve their skills, generate and disseminate new knowledge, form and multiply the knowledge capital of business. This paper aims to investigate a pairwise interconnection between higher education indicators and sets of parameters characterizing knowledge creation, impact, and diffusion. The following higher education indicators are used: expenditure on education, tertiary enrollment, graduates in science and engineering, tertiary inbound mobility, researcher, gross expenditure on R&D, top 3 global corporate R&D investors, top 3QS university ranking. Knowledge creation indicators are patents by origin, PCT patents by origin, utility models by origin, scientific and technical articles, citable documents, H-index. Knowledge impact is characterized through labor productivity growth, new businesses, software spending, ISO 9001 quality certificates, high-tech manufacturing. Knowledge diffusion parameters include intellectual property receipts, production and export complexity, high-tech exports, ICT services exports. The information base of the study is the data of the Global Innovation Index Report from the World Intellectual Property Organization for 40 European countries (selected depending on the availability of statistics) for 2022, research method – Canonical Correlation Analysis. The strongest positive correlation was found between higher education indicators and knowledge creation parameters. The second position takes connection between higher education indicators and knowledge diffusion parameters, the third – between higher education indicators and knowledge impact indicators. Among the higher education indicators, the most significant were gross expenditure on R&D, top 3 global corporate R&D investors, top 3 QS university ranking.

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INTRODUCTION

The gradual transition to knowledge-based social relations, caused by rapid globalization and anticipatory scientific and technological progress, also caused a change in the role of innovations. The knowledge-based economy is traditionally understood as one based on knowledge and information as the main factors of production (OECD, 1996), with innovation considered a key driver. It leads to transformation in all sectors of the economy, where knowledge-based industries or sectors, knowledge-based jobs and workers, etc., arise. Separately, they even talk about the creation of knowledge capital at the enterprise level, which guarantees their success (Vidic, 2022).

One of the bright manifestations of the knowledge-based economy is a change in approaches to the very essence of education, which is beginning to be considered a lifelong process. There is a need for employees with higher education and the ability to constantly learn and improve their skills, developing numerous soft skills (Tierney & Lanford, 2016). After all, this is the only way to get highly educated human capital capable of generating and spreading new knowledge, ideas, and innovations.

The knowledge-based economy also requires higher education institutions to comply with the requirements of a new type of economic and social relations, transforming and adapting them. For example, the simultaneous need to massify higher education is intertwined with the tendency to decrease its budgetary funding, moving to performance-based funding (Tierney & Lanford, 2016). Implementing advanced achievements of information, communication and interactive technologies in the educational process requires updating technical support and personnel qualifications, etc. (Guàrdia et al., 2021). However, when examining the importance of transformations in higher education according to knowledge-based economy, attention should be focused on the importance of knowledge creation through teaching and research, its impact, and dissemination.

1. LITERATURE REVIEW

The need for innovations is often associated with the fact that they can form the critical competitive advantages of a particular business entity (Onileowo et al., 2021), improve their performance or, in other words, productivity (Morris, 2018; Nohut & Balaban, 2022) on meso-levels, in addition, it has been proven that innovative activity contributes to the creation of consumer value and value (Harshad, 2022). Separate studies on identifying and developing specific instruments for financing innovations in business companies are singled out (Strielkowski et al., 2022; Nwaibe et al., 2022).

The positive impact of innovative activity on the state of the labor market (Elamir & Mousa, 2022), the general development of the social sector (Lyeonov et al., 2021), as well as on stimulating the transition to Industry 4.0/5.0 in the context of the development of the additive economy (Melnyk et al., 2022) and the transformation of the reproduction of a country's human capital in the context of the formation of the necessary competencies of future specialists (Melnyk et al., 2021) is noted at the macro level.

One of the most common ways of stimulating innovation is investing in research and development (R&D) (Mason et al., 2019), the development of intellectual property (Soumadi, 2023), and directly in higher education (Yu, 2023). In addition, numerous studies confirm that the level of education is essential in the formation of innovations, the accumulation of human capital and the socio-economic development of a region or country, the level of its national security (Samusevych et al., 2021; Cammeraat et al., 2021; Chentukov et al., 2021; Safarov et al., 2022; Karabayev et al., 2023). In particular, Yu et al. (2023) argue that increased spending on education can increase the innovative capacity of human capital and enhance their ability to perceive and apply new technologies, leading to transformation and knowledge transfer. Here it is important to note that innovations in education have an impact on accelerating the achievement of sustainable development goals (Vorontsova et al., 2020; Dong et al., 2022), in particular, overcoming problems related to population migration (Pudryk et al., 2023), unemployment and labor market imbalance (Oliinyk et al., 2020), excessive consumption of natural resources and environmental pollution, etc. (Sotnyk, 2012).

An essential aspect of forming and disseminating knowledge at higher education institutions is the conduct of qualitative scientific research, which should have a high level of social effectiveness (Perevozova et al., 2020). Didenko et al. (2022) proved that there is a functional relationship between the quality of scientific activity in the context of innovative development and a country's socio-economic development.

The study of the connection between innovation and higher education proved that by the end of 2022, the number of publications on this topic in the Scopus database was more than 10,000, covering various subject areas (34.8% of them belonged to social sciences, 10, 2% – business and management, 4% – economics, econometrics, and fi-

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nance). Similar results in the Web of Science made it possible to obtain more than 92,000 scientific works devoted to the connection of innovations and higher education, indicating this topic's sufficiently high relevance. In general, such studies can be grouped into the following blocks.

Changing the essence of higher education institutions through the prism of university-industry collaboration, which contributes to the creation and development of innovations, is widely discussed in scientific circles and is primarily manifested through the prism of the triple helix model (the form of relations between the academy, industry and government). In such conditions, entrepreneurial universities with innovation laboratories are formed (Kaya et al., 2023), which become a source of innovation (Guerrero et al., 2016) and allow not only to commercialize the process of knowledge creation but also to deepen the study of their impact and dissemination (D'Este & Perkmann, 2011), and as a result, form the core of innovation clusters in countries (Bugrov et al., 2021). Nahla (2023), based on the analysis of research partnerships between higher education institutions and business representatives, proves that despite the existing progress, the process could be more robust and superficial and needs further development and strengthening.

Transformation of higher education system according to knowledge-based economy changed educational process, methods and technologies of learning and teaching. Typical examples are the transition to distance or online learning (Raisiene et al., 2022), the high level of development and distribution of massive online courses (MOOCs) and their gradual use in the educational process as separate elements (Al-Imarah et al., 2021), using elements of virtual reality and artificial intelligence, open-source courses (Skrynnyk & Vasilyeva, 2020), etc. Ponomarenko et al. (2021) use the term innovation-active university, which is formed in modern conditions of digitalization of society and which uses numerous innovative tools in learning and teaching.

It should be noted here that they are quite closely related to the understanding of the third mission of universities as service to society, which can be manifested, including in the context of generating, using, and disseminating knowledge (Secundo et al., 2017), as well as to ensure peace and security (Petrushenko et al., 2023). In some studies, emphasis is placed on implementing corporate social responsibility practices in the activities of higher education institutions (Bila et al., 2020), which is also a sign of innovative changes.

Essential vectors of scientific research are works devoted to the effectiveness of the influence of higher education on the formation of innovations and the identification of the main challenges or barriers on their way. Thus, in separate works (Ávila et al., 2017; Aleixo et al., 2018), the sustainability of higher education institutions is investigated, which in turn guarantees sustainable investments. Artyukhov et al. (2021) propose a theoretical model of sustainable university activity to ensure not only the quality of education (through the prism of SDG 4) but also the promotion of affordable and clean energy practices (SDG 7). When studying the influence of educational institutions on the formation and spread of innovations, some scientists take the total quality management system as a basis (Wu & Gu, 2022).

Numerous challenges on this path arose as a result of the COVID-19 pandemic (Smiianov et al., 2020; García-Morales et al., 2020; MacNeil et al., 2022) because they contributed to the deterioration of the physical and psychological condition of the population decrease in their well-being, and also provided for a forced transition to online learning and digitization of educational resources in a relatively short period, etc. Despite the numerous achievements of digital technologies in the educational process, collective learning still has a more effective result than individual one, forming the skills of interpersonal interaction, cognitivism and constructivism, etc. (Khushk et al., 2022), directly forming the social capital of a person as a guarantee of successful development (Ievdokymov et al., 2020), as well as the basis for successful professional communication and development, etc. (Mujtaba & Meyer, 2022).

Also, the challenges should include behavioral prejudices that have a significant impact on making sound financial decisions, which can be critically understood in the learning process (Isik, 2022), as well as the low level of financial literacy and inclusiveness of the population, the increase of which must be ensured on levels of educational and educational activities (Antoniuk et al., 2022; Kuzior et al., 2022).

In this regard, the aim of the article is to investigate a pairwise interconnection between higher education indicators and sets of parameters characterizing knowledge creation, impact, and diffusion.

2. RESEARCH METHODS

To achieve the purpose, a sample of 40 countries belonging to the geographical region of Europe and for which open statistical information is available for the analyzed period was formed: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Albania, Andorra, Belarus, Bosnia and Herzegovina, Iceland, Montenegro, North Macedonia, Norway, Republic of Moldova, Serbia, Switzerland, Ukraine, United Kingdom.

The data of the World Intellectual Property Organization (WIPO), presented in the form of the Global Innovation Index (GII) Report for 2022 (WIPO, 2022), acted as the information base. This database represents the most systematic and reliable analysis of the main trends in innovative development. Its value in this specific study is represented by the fact that a separate block of the composite GII is devoted to education, research, and human capital formation. They are considered one of the input factors responsible for forming innovations. Also, this index includes knowledge and technology outputs, which will be used within the scope of this study. Input data and their characteristics are presented in Table 1.

Canonical Correlation Analysis (CCA) is used as the basis of calculations because it allows us to reveal relationships between individual blocks or sets of indicators using latent or canonical variables (Abdi et al., 2018). Suppose that the first set of indicators is the matrix

$$X = \begin{pmatrix} x_1 \\ \dots \\ x_n \end{pmatrix}, \quad (1)$$

the second is the matrix

$$Y = \begin{pmatrix} y_1 \\ \dots \\ y_m \end{pmatrix}. \quad (2)$$

Table 1. Input data description

Variables list	Units	Symbols
FIRST SET (THE *U*-VARIABLES)		
Expenditure on education	% GDP	u_1
Tertiary enrolment	% gross	u_2
Graduates in science and engineering	%	u_3
Tertiary inbound mobility	%	u_4
Researchers	FTE/mn pop.	u_5
Gross expenditure on R&D	% GDP	u_6
Global corporate R&D investors, top 3	mln USD	u_7
QS university ranking, top 3	unit	u_8

SECOND SET (THE *V*-VARIABLES)								
1. Knowledge creation			**2. Knowledge impact**			**3. Knowledge diffusion**		
Patents by origin	bln PPP USD GDP	v_1	Labor productivity growth	%	v_6	Intellectual property receipts	%	v_{11}
PCT patents by origin		v_2	New businesses	th. pop. 15-64	v_7	Production and export complexity		v_{12}
Utility models by origin		v_3	Software spending	% GDP	v_8	High-tech exports		v_{13}
Scientific and technical articles		v_4	ISO 9001 quality certificates	bln PPP USD GDP	v_9	ICT services exports		v_{14}
Citable documents *H*-index	unit	v_5	High-tech manufacturing	%	v_{10}			

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Within the scope of the study, it is necessary to find the following linear combinations between them (for example, U for X and V for Y) that have the highest level of correlation, i.e.:

$$U_n = a_{n1}X_1 + \ldots + a_{nn}X_n, \quad (2)$$

$$V_m = b_{m1}Y_1 + \ldots + b_{mm}Y_m, \quad (3)$$

where a, b – coefficients of the model with variables; n, m – the number of X and Y indicators, respectively.

At the same time, canonical correlation coefficients (R_c) are calculated using the following equation:

$$R_{c(i)} = \frac{\operatorname{cov}(U_i V_i)}{\sqrt{\operatorname{var}(U_i)\operatorname{var}(V_i)}}, \quad (4)$$

where i_{th} – canonical functions; cov – covariance between U and V; var – variance of U or V.

CCA is proposed to be carried out as a sequence of the following steps within the scope of this study:

- determination of the raw coefficients of the model, the optimal number of significant canonical functions (using Wilks' lambda, Hotelling's trace, Pillai's trace, and Roy's largest root tests)
- checking the significance of the raw coefficients of the model within the canonical functions using standardized canonical coefficients and canonical loadings;
- receiving canonical correlation coefficients (R_c) and redundancy index (R_d);
- validate the obtained canonical correlation model.

All calculations were carried out based on the software complex Stata/SE 12.0.

3. RESULTS

Compliance of variables with the normal distribution law is an important condition for conducting CCA, which was checked using the Shapiro-Wilk and Shapiro-Francia tests. The test results for U-variables are presented in Table 2.

The findings indicate the problem of the $u_2 - u_4$ variables, which were excluded from further analysis. This solution is optimal because it allowed reducing the sample of U-variables to 5 units. For V-variables, the check took place similarly; there were no reductions.

Going directly to the CCA results, a detailed analysis of the relationship between the first set (u_1 – u_8) and knowledge creation second set (v_1 – v_5) is presented. For the remaining blocks, the analysis was performed similarly. The results of determining raw coefficients and the optimal number of canonical functions are given in Table 3. They indicate the feasibility of leaving only two canonical functions; the results for the knowledge impact and knowledge diffusion blocks are similar.

The results of testing the significance of standardized canonical coefficients are shown in Table 4. Thus, within the first canonical function, the indicators u_6 (gross expenditure on R&D), u_7 (glob-

Table 2. Testing *U*-variables for normal distribution

Variable	Obs.	Shapiro-Wilk W test				Shapiro-Francia W' test			
		W	V	z	Prob. > z	W'	V'	z	Prob. > z
u_1	40	0.981	0.744	−0.623	0.733	0.977	1.010	0.019	0.492
u_2	40	0.911	3.511	2.643	0.004	0.891	4.778	2.915	0.002
u_3	40	0.982	0.728	−0.668	0.028	0.982	0.779	−0.465	0.009
u_4	40	0.829	6.747	4.017	0.000	0.820	7.883	3.849	0.000
u_5	40	0.964	1.435	0.760	0.224	0.974	1.121	0.213	0.415
u_6	40	0.944	2.203	1.662	0.048	0.956	1.927	1.223	0.111
u_7	40	0.863	5.417	3.556	0.080	0.951	2.130	1.409	0.079
u_8	40	0.902	3.869	2.847	0.072	0.967	1.452	0.696	0.243

Table 3. Determination of raw coefficients and the optimal number of canonical functions for *U*-variables and knowledge creation of *V*-variables

1. Raw coefficients analyses											
Variable	*U*-variables					Variable	*V*-variables				
	1	2	3	4	5		1	2	3	4	5
u_1	0.000	0.010	0.049	–0.019	0.046	v_1	0.004	0.018	0.008	0.122	0.012
u_5	–0.007	0.028	–0.032	–0.085	–0.049	v_2	0.006	0.001	–0.022	–0.099	0.026
u_6	0.013	0.037	0.020	0.138	0.001	v_3	–0.001	0.006	0.034	–0.020	0.016
u_7	0.010	–0.008	–0.035	0.008	0.043	v_4	–0.001	0.036	0.020	–0.002	–0.024
u_8	0.022	–0.034	0.038	–0.022	–0.032	v_5	0.031	–0.035	0.008	–0.028	–0.022

2. Tests of significance analyses						
Test statistics	Statistic	df1	df2	F	Prob. > F	
Wilks' lambda	0.010	25	112.947	11.040	0.000	a
Pillai's trace	2.081	25	170.000	4.846	0.000	a
Lawley-Hotelling	21.547	25	142.000	24.478	0.000	a
Roy's largest root trace	19.062	5	34.000	129.624	0.000	u
Canonical correlations 1-5	0.010	25	112.947	11.040	0.000	a
Canonical correlations 2-5	0.203	16	95.344	4.084	0.000	a
Canonical correlations 3-5	0.583	9	78.030	2.151	0.035	a
Canonical correlations 4-5	0.797	4	66.000	1.977	0.108	e
Canonical correlations 5	0.957	1	34.000	1.546	0.222	e

al corporate R&D investors) and u_8 (QS university ranking) were found to be significant within the limits of *U*-variables and v_5 (citable documents H-index) among *V*-variables. Within the second canonical function, a small change is noted among *U*-variables – u_6 (researchers) instead of u_6 turned out to be significant.

Table 5 shows the correlations established within and between *U*-variables and *V*-variables, presented as heatmaps. These coefficients are the basis for forming canonical loadings and linear combinations between sets. Depending on the color, they take either sufficiently high (green) or low or negative (red) values.

Table 4. Verification of the significance of standardized canonical coefficients for *U*-variables and knowledge creation of *V*-variables

Canonical functions	Variables	Coef.	Std. err.	t	P > |t|	95% Conf. Interval	
U_1 canonical functions	u_1	0.000	0.003	–0.040	0.966	–0.006	0.005
	u_5	–0.007	0.004	–1.670	0.103	–0.015	0.001
	u_6	0.013	0.006	2.300	0.027	0.002	0.025
	u_7	0.010	0.002	4.470	0.000	0.005	0.015
	u_8	0.022	0.003	8.430	0.000	0.017	0.028
V_1 canonical functions	v_1	0.003	0.005	0.710	0.480	–0.006	0.013
	v_2	0.006	0.004	1.450	0.156	–0.002	0.014
	v_3	–0.001	0.002	–0.710	0.480	–0.005	0.002
	v_4	–0.001	0.002	–0.530	0.600	–0.005	0.003
	v_5	0.031	0.002	13.330	0.000	0.026	0.036
U_2 canonical functions	u_1	0.009	0.009	1.070	0.290	–0.008	0.027
	u_5	0.028	0.013	2.100	0.043	0.001	0.055
	u_6	0.037	0.018	2.050	0.047	0.001	0.074
	u_7	–0.008	0.007	–1.150	0.256	–0.023	0.006
	u_8	–0.034	0.008	–3.990	0.000	–0.051	–0.017
V_2 canonical functions	v_1	0.018	0.016	1.170	0.250	–0.013	0.050
	v_2	0.001	0.013	0.040	0.964	–0.026	0.027
	v_3	0.006	0.005	1.050	0.301	–0.005	0.017
	v_4	0.036	0.006	6.020	0.000	0.024	0.049
	v_5	–0.035	0.007	–4.680	0.000	–0.050	–0.020

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Table 5. Correlation matrices within and between *U*-variables and knowledge creation *V*-variables in the form of heatmaps

Correlations within U-variables						Correlations within V-variables						Correlations between U-variables and V-variables					
Variable	u_1	u_5	u_6	u_7	u_8	Variable	v_1	v_2	v_3	v_4	v_5	Variable	u_1	u_5	u_6	u_7	u_8
u_1	1	–	–	–	–	v_1	1	–	–	–	–	v_1	0.521	0.755	0.817	0.806	0.744
u_5	0.656	1	–	–	–	v_2	0.933	1	–	–	–	v_2	0.513	0.776	0.771	0.773	0.65
u_6	0.628	0.917	1	–	–	v_3	−0.082	−0.224	1	–	–	v_3	0.118	−0.228	−0.176	−0.23	−0.07
u_7	0.476	0.768	0.762	1	–	v_4	0.471	0.519	−0.36	1	–	v_4	0.543	0.735	0.718	0.46	0.398
u_8	0.403	0.68	0.737	0.822	1	v_5	0.71	0.59	−0.07	0.42	1	v_5	0.391	0.641	0.72	0.839	0.949

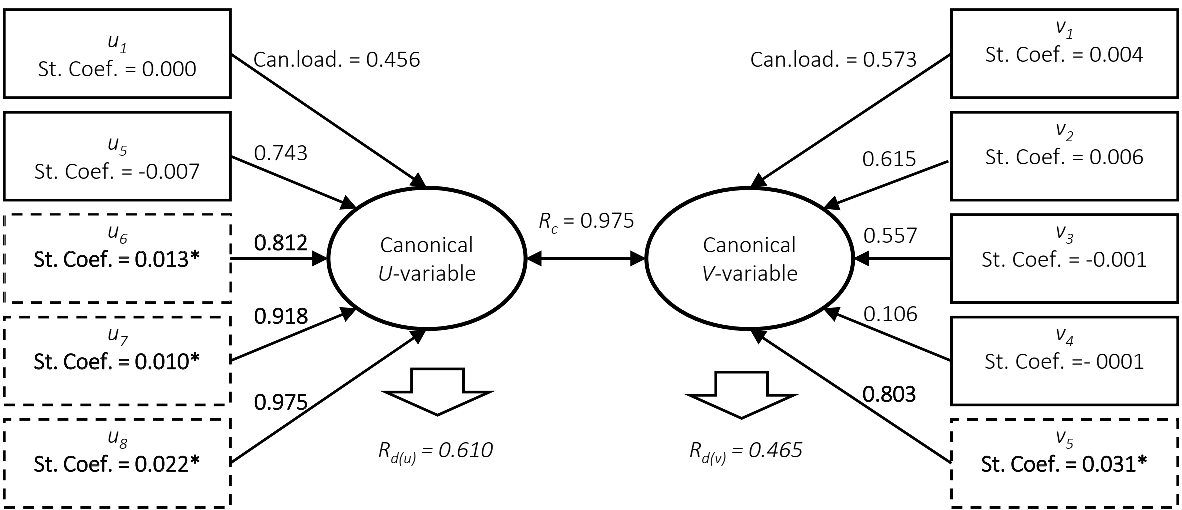
All this allows us to estimate this model's canonical loadings and form the following simplified model form for the first and second canonical functions (Figure 1-2). It shows standardized canonical coefficients (significant highlighted), canonical loadings, canonical correlation coefficients (R_c) and redundancy index (R_d).

Canonical correlation coefficients (R_c), indicating the strength of the connection between two pairs of sets, are sufficiently large, both for the first and for the second canonical function (0.975 and 0.807, respectively). However, redundancy indices (R_d), which indicate the proportion of variance of one set due to another, are much better for the first canonical function. Gross expenditure on R&D, global corporate R&D investors and QS university ranking for *U*-variables and citable documents H-index for knowledge creation *V*-variables were significant within the first canonical function.

Similarly, analysis of the blocks of knowledge impact and diffusion indicators is presented in Table 6.

Note that canonical correlation coefficients also have quite high values for the blocks of knowledge impact and knowledge diffusion. Instead, the redundancy indices indicate that the first canonical function for both models has a higher quality and is more significant because a larger share of the variance of one data set determines the other. Using standardized canonical coefficients, the following significant variables were identified (it is described only the first canonical function):

- QS university ranking for *U*-variables and software spending set, ISO 9001 quality certificates, high-tech manufacturing, knowledge impact for knowledge impact *V*-variables;



Note: * where St. Coef – standardized canonical coefficients, Can. load – canonical loadings.

Figure 1. Simplified scheme of the canonical correlation model for the first canonical function for *U*-variables and knowledge creation *V*-variables

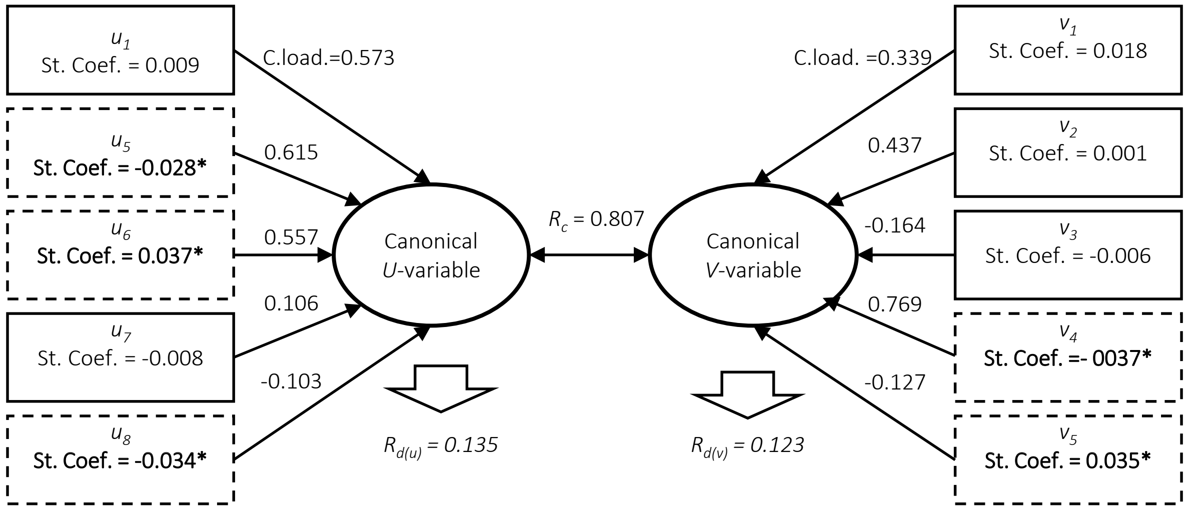


Figure 2. Simplified scheme of the canonical correlation model for the second canonical function for *U*-variables and knowledge creation *V*-variables

Table 6. CCA results for *U*-variables and knowledge impact and knowledge diffusion *V*-variables

1. *U*-variables and knowledge impact *V*-variables						
Variable	**1st canonical function**			**2nd canonical function**		
	Stand. coeff.	**Can. loadings**	**R_d**	**Stand. coeff.**	**Can. loadings**	**R_d**
u_1	0.001	0.508		0.057*	**0.743**	
u_5	0.009	0.812		0.036	0.232	
u_6	−0.004	0.821	0.496	0.064*	**0.643**	0.043
u_7	0.007	0.915		−0.017	−0.091	
u_8	0.024*	**0.971**		0.009	−0.069	
v_6	−0.002	−0.147		0.054*	**0.675**	
v_7	0.006	0.189		0.021*	**0.546**	
v_8	0.029*	**0.904**	0.234	0.015	−0.040	0.062
v_9	0.008*	**0.562**		−0.012	−0.323	
v_{10}	0.019*	**0.766**		−0.018	−0.201	
R_c	0.858			0.585		
2. *U*-variables and knowledge diffusion *V*-variables						
Variable	**1st canonical function**			**2nd canonical function**		
	Stand. coeff.	**Can. loadings**	**R_d**	**Stand. coeff.**	**Can. loadings**	**R_d**
u_1	−0.002	0.458		0.026	0.381	
u_5	−0.009	0.768		0.012	0.186	
u_6	0.024*	**0.856**	0.501	−0.053	−0.005	0.026
u_7	0.009	0.909		0.045*	**0.396**	
u_8	0.019*	**0.962**		0.039*	**0.113**	
v_{11}	0.027*	**0.749**		0.026*	**0.642**	
v_{12}	0.029*	**0.690**	0.279	0.029*	**0.667**	0.096
v_{13}	−0.008	0.647		−0.002	−0.419	
v_{14}	0.013*	**0.565**		0.004	0.128	
R_c	0.874			0.606		

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- Gross expenditure on R&D, QS university ranking for *U*-variables set and intellectual property receipts, production and export complexity and ICT services exports for knowledge diffusion *V*-variables.

4. DISCUSSION

A comparison of the results obtained within the scope of this study with similar scientific directions allowed us to note the following. Based on cluster analysis, Jankowska et al. (2017) prove that highly innovative inputs only sometimes contribute to highly innovative outputs. However, this study did not allow identifying individual components of inputs or outputs, which have greater or lesser weight, which is quite essential in the context of the significance of these factors. Within the scope of this study, the emphasis was placed on this, which made it possible to identify which higher education indicators significantly impact the formation of innovations through the prism of knowledge creation, knowledge impact, and knowledge diffusion.

Using the structural equation model, Sohn et al. (2016) studied the relationship between GII components, among which business sophistication and infrastructure were found to be the most powerful as of 2013. Similar is the study by Gogodze (2016), which confirms that the interaction between GII components depends on a country's economic development level. In particular, effective institutional capital management is a key driver of innovation success for non-high-income countries. Within the scope of this work, the importance of developing the economic environment for the formation of innovations is not excluded. However, the work emphasizes the connection between educational components and the rest of the indicators that form innovations. In particular, the obtained results are valuable for guiding the internal policy of higher education institutions to promote innovative development.

In the context of research on the relationship between education and innovation results, the work of Yüregir et al. (2022). Based on several statistical and econometric methods and models, the connection between HEEACT and ARWU rankings of universities and GII, which varies depending on economic-political groups, is confirmed. It should be noted that the analysis was conducted only on the example of European countries. It did not allow us follow the variation of results in countries with different income levels or from other economic and political groups. At the same time, within the scope of this work, the use of not only university ranking indicators6 but also a more extensive list (expenditure on education, research indicators, percentage of enrollment in higher education institutions, etc.) allowed us to obtain a more reasonable and valuable result.

It is worth noting that a separate limitation of this work is the period because this study is aimed at identifying the impact of higher education on innovative results, particularly on knowledge creation, impact and diffusion as of 2022. However, these ideas will be the basis for further in-depth research and development, which will allow us to trace the dynamics and compare them with pre-pandemic values.

Despite the existing limitations, this work achieves the goal of documenting the impact of higher education on the formation of innovations through the prism of knowledge creation, knowledge impact and knowledge diffusion based on empirical results and forms directions for further, more specifically targeted research.

CONCLUSION

This work is devoted to the analysis of pairwise interconnections between higher education indicators and sets of parameters characterizing knowledge creation, impact, and diffusion on the example of 40 European countries. Based on individual components of the GII, an information base of research was formed, covering the leading indicators of the functioning of higher education and knowledge and technology outputs. The relationship between them was explored using Canonical Correlation Analysis, which allows for the detection of relationships between two sets of data.

The obtained canonical correlation coefficients confirmed a sufficiently strong positive relationship. At the same time, the study conducted confirms that the amount of variance of one set of data, which determines the second set, is much higher for the first canonical functions (for example, for the first pair of sets for higher education, it is 61.0%, and for knowledge creation – 46.5%).

In a more detailed dimension, the following dependencies were confirmed: Firstly, higher education, among which significant factors included R&D expenditures and investments, as well as belonging to the QS university ranking, has a positive effect on knowledge creation (citable documents H-index turned out to be significant). Secondly, higher education (in particular, QS university ranking) has a positive effect on knowledge impact (software spending, ISO 9001 quality certificates, high-tech manufacturing, knowledge impact). Thirdly, higher education (gross expenditure on R&D, QS university ranking) has a positive effect on knowledge diffusion (intellectual property receipts, production and export complexity and ICT services exports).

The results obtained show that belonging to the QS university ranking has a sufficiently significant influence on the formation and spread of innovations, which can be taken into account both at the policy level of individual higher education institutions among European countries and in the context of the activities of individual organizations, such as the European Network of Innovative Higher Education Institutions (ENIHEI), in the implementation of the Digital Education Action Plan (2021–2027), etc.

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