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MANAGEMENT OF THE HIGHER EDUCATION INSTITUTIONS INNOVATIVE POTENTIAL: FORMALIZATION AND EVALUATION

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Abstract

The purpose of this paper is to improve the innovation management of higher education institutions, taking into account the peculiarities of formalizing the structure of innovation potential, ranking, and statistical evaluation. It was used the following methods: comparative analysis, induction and deduction, sum of places method, graphic expression of statistical data, correlation analysis, linear multifactorial regression analysis, and others. The authors proposed to solve the problem of formalization of innovative potential through the systematization of 16 indicators into 4 components: physical capital potential, human capital potential, potential of government regulation, and higher education services market potential. The innovation potential management ranking was developed and tested according to the data of 20 Ukrainian pedagogical higher education institutions, using the sum of places method. It is proved the inverse relationship between the number of enrolled students and the higher education institutions sums of places. For the first time, a statistical multicollinearity test was developed and implemented as part of the correlation analysis. Statistical evaluation of the impact of innovation potential on the higher education institutions development has been improved using linear multivariate regression analysis. This evaluation shows that the most significant is the higher education services market potential.

Keywords

Component – Correlation analysis – Multicollinearity – Regression analysis – Sum of places method

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Introduction

Innovation is increasingly important in the activities of higher education institutions (HEIs). It is institutions of higher education that are directly involved in the state's innovation process. HEIs are the subjects of the innovation process when developing innovations and new technologies. HEIs are also subjects of the innovation process when using the advanced ideas and technologies to educate students. Also, the learning process becomes the object of the innovation process today. Thus, subjectivity, as well as the objectivity of HEIs in the innovation process, are formed in the process of managing innovation potential.

Management of the innovation potential of HEIs is to organize and plan the components of the innovation potential, to control their formation and use, and to motivate the staff involved in this process. The innovation potential of HEIs should be understood as the set of interconnected resources, factors, and conditions of innovation that form the basis for enhanced reproduction. However, in the analysis of components of the innovation potential of HEIs there is an objective problem of formalization and statistical evaluation.

The relevance and practical value of the article are due to several facts. Firstly, the innovativeness of education is the main resource and a component of the innovative potential of HEIs. Secondly, formalization of the components of the innovation potential of a higher education institution is carried out taking into account the potentials of physical capital and human capital, state regulation, and the market conditions of higher education services. Thirdly, the availability of innovative potential enhances the competitive advantages of the higher education institution in the higher education services market, so it is advisable to make a statistical evaluation of its effectiveness in the context of a uniform sample of universities and across the country.

Literature review

Among the great number of researchers of theoretical and applied aspects of innovation management, we should distinguish such as Enarson and Drucker[1], Berg and Östergren[2], Kozma[3], Lueddeke[4], Schneckenberg[5], which laid a foundation for evaluating the effectiveness of innovation in higher education and its impact on economic development. Analyzing the scientific publications of the last 5 years in the context of our research, we note that they mostly investigate the innovative processes that take place in the interaction "HEIs – learning environment – national (regional) economy". Thus, Fetschenko et al. investigated diverse approaches to managing innovative integrated

[1] Harold Enarson and Peter Drucker, "Innovation in higher education", The Journal of Higher Education Vol: 31 num 9 (1960): 495–501, https://doi.org/10.1080/00221546.1960.11777628.

[2] Berg Barbro and Östergren Bertil, "Innovation processes in higher education", Studies in Higher Education Vol: 4 issue 2 (1979): 261–268, https://doi.org/10.1080/03075077912331377027.

[3] B. Kozma Robert, "A grounded theory of instructional innovation in higher education", The Journal of Higher Education vol: 56 num 3 (1985): 300–319, https://doi.org/10.1080/00221546.1985.11780692.

[4] R. Lueddeke George, "Toward a constructivist framework for guiding change and innovation in higher education", The Journal of Higher Education Vol: 70 num 3 (1999): 235–260, https://doi.org/10.1080/00221546.1999.11780763.

[5] Dirk Schneckenberg, "Understanding the real barriers to technology-enhanced innovation in higher education", Educational Research Vol: 51 issue 4 (2009): 411–424, https://doi.org/10.1080/00131880903354741.

structures of education, business, and science at the regional level[6]. Benneworth, Pinheiro, and Karlsen investigated the impact of universities on institutional changes in regional innovation systems through the phenomenon of "place-based leadership"[7]. Ryan, and Daly identified the main problems, barriers, and factors for knowledge-based and investment-driven economic development in the UAE[8]. Al-Imarah, and Shields investigated the role of Massive Open Online Courses in the learning environment and proved that these modern innovative learning technologies are not yet capable of radically altering existing higher education models but can be an alternative in the higher education services market[9]. Giannopoulou, Barlatier, and Pénin analyzed the innovative characteristics (impacts and types of innovation and internal R&D investments) of firms that collaborate with research and technology organizations versus universities[10]. Yáñez, Uruburu, Moreno, and Lumbreras analyzed the managerial changes in the basic spheres of education and science on the example of HEIs and proved their key role in the sustainable development of society[11]. Vargas et al. developed ways to overcome the difficulties on the road to sustainable development, which arise in connection with economic growth, and investigated the role of the UK HEIs in this process[12]. Giuri, Munari, Scandura, and Toschi identify theoretically and empirically three university knowledge transfer strategies: income-generation strategy, service-to-faculty strategy, and local development strategy based on an empirical analysis of a survey of 178 university technology transfer office managers across European universities, combined with additional data sources[13]. Omelyanenko et al. analyzed the technology transfer as an important source of innovation creation and an integral part of business development; they considered the new specifics of technology transfer management within the Education 3.0 paradigm too[14]. Findler,

[6] Valentina Fetschenko; Elena Shadoba; Yuriy Katkow; Natalya Shchelikova and Nikolay Glushak, "Management of innovative integrated structures of education, business and science at the regional level", Procedia – Social and Behavioral Sciences Vol: 214 (2015): 243–251, https://doi.org/10.1016/j.sbspro.2015.11.673.

[7] Paul Benneworth; Rómulo Pinheiro and James Karlsen, "Strategic agency and institutional change: investigating the role of universities in regional innovation systems (RISs)", Regional Studies Vol: 51 issue 2 (2017): 235–248, https://doi.org/10.1080/00343404.2016.1215599.

[8] James C. Ryan and M. Daly Timothy, "Barriers to innovation and knowledge generation: The challenges of conducting business and social research in an emerging country context", Journal of Innovation & Knowledge, Vol: 4 num 1 (2018): 47–54, https://doi.org/10.1016/j.jik.2017.10.004.

[9] Ahmed Al-Imarah and Robinn Shields, "MOOCs, disruptive innovation and the future of higher education: A conceptual analysis", Innovations in Education and Teaching International Vol: 56 issue 3 (2018): 258–269, https://doi.org/10.1080/14703297.2018.1443828.

[10] Eleni Giannopoulou; Pierre-Jean Barlatier and Julien Pénin, "Same but different? Research and technology organizations, universities and the innovation activities of firms", Research Policy Vol: 4 issue 1 (2018): 223–233, https://doi.org/10.1016/j.respol.2018.08.008.

[11] Susana Yáñez; Ángel Uruburu; Ana Moreno and Julio Lumbreras, "The sustainability report as an essential tool for the holistic and strategic vision of higher education institutions", Journal of Cleaner Production vol: 207, no. 1 (2018): 57–66, https://doi.org/10.1016/j.jclepro.2018.09.171.

[12] Valeria Vargas Ruiz; Rebecca Lawthom; Alicia Prowse; Sally Randles and Konstantinos Tzoulas, "Sustainable development stakeholder networks for organisational change in higher education institutions: A case study from the UK", Journal of Cleaner Production Vol: 208 (2018): 470–478, https://doi.org/10.1016/j.jclepro.2018.10.078.

[13] Paola Giuri; Federico Munari; Alessandra Scandura and Laura Toschi, "The strategic orientation of universities in knowledge transfer activities", Technological Forecasting and Social Change Vol: 138 (2018): 261–278, https://doi.org/10.1016/j.techfore.2018.09.030.

[14] Vitaliy Omelyanenko; Inna Semenets-Orlova; Olena Khomeriki; Lyudmyla Lyasota and Yuliia Medviedieva, "Technology transfer management culture (education-based approach)", Problems and Perspectives in Management Vol: 16 num 3 (2019): 454–463, http://dx.doi.org/10.21511/ppm.16(3).2018.36.

Schönherrand, and Stacherl analyzed to what extent sustainability assessment tools are capable of measuring the impacts that HEIs have on sustainable development[15]. The team of authors, led by editors Bryan, and Clegg, has explored the methodological and applied aspects of innovative assessment in higher education[16].

However, the scientific problem of formalization and statistical evaluation of the structure of innovation potential of higher education institutions remains insufficiently studied in innovation management, despite the completeness of the studies conducted by the above-mentioned authors.

The main purpose of the article is to improve the innovation management of HEIs, taking into account the peculiarities of formalizing the structure of innovation potential, rating, and statistical evaluation.

Methodology

Higher education is one of the most innovative areas of social development. HEIs produce new ideas and technological solutions primarily through private and state investment in human capital, which provides long-term social development based on the knowledge economy. Therefore, managing the innovation potential of HEIs is relevant for research. It should also be noted that these processes are significantly different, depending on the economic development of the country. Our research interests include Ukraine as a European country with a transitive economy. In Ukraine, in the 2018-2019 academic year, educational services were provided by 289 HEIs – universities, academies, and institutes[17]. Pedagogical HEIs have a special mission as they train teachers of preschool, primary, secondary, and post-secondary levels in Ukraine. Therefore, their contribution to the development of human capital in Ukraine can be considered the most significant of all HEIs. That is why, in the context of our study, we will analyze the effectiveness of innovative potential management of pedagogical HEIs, of which there are 20 in Ukraine (Table 1).

HEI	**Abbreviations of HEIs**	**Legal addresses**	**The Number of Enrolled Students (*NES*)**
Berdyansk State Pedagogical University	BSPU	4, Schmidt Str., Berdiansk, Zaporizhia region, Ukraine, 71100	2177
Bogdan Khmelnitsky Melitopol State Pedagogical University	BKMSPU	20, Hetmanska Str., Melitopol, Zaporizhia region, Ukraine, 72300	1757
Borys Grinchenko Kyiv University	BGKU	18/2, Bulvarno-Kudriavska Str., Kyiv, Ukraine, 04053	3105
Donbas State Pedagogical	DSPU	19, H. Batiuk Str., Sloviansk,	1475

[15] Florian Findler, Schönherrand Norma, and Stacherl Barbara, “Assessing the impacts of higher education institutions on sustainable development – An analysis of tools and indicators”, Sustainability Vol: 11 num 1 (2019): 1–19, https://doi.org/10.3390/su11010059.

[16] Cordelia Bryan and Karen Clegg (eds.), Innovative Assessment in Higher Education: A Handbook for Academic Practitioners (New York: Routledge, 2019), 256.

[17] Services search entrants 2010-2019, “Ranking lists 2019”, https://abit-poisk.org.ua/rate-review (accessed June 28, 2020).

University		Donetsk region, Ukraine, 84116	
Drohobych Ivan Franko State Pedagogical University	DIFSPU	24, Ivan Franko Str., Drohobych, Lviv region, Ukraine, 82100	1848
Hryhorii Skovoroda Pereiaslav-Khmelnytskyi State Pedagogical University	HSPKSPU	30, Sukhomlynskyi Str., Pereiaslav, Kyiv region, Ukraine, 08401	2388
H. S. Skovoroda Kharkiv National Pedagogical University	HSSKNPU	2, Valentynivska Str., Kharkiv, Ukraine, 61000	2111
Khmelnytskyi Humanities and Pedagogical Academy	KHPA	139, Proskurivskoho Pidpillia Str., Khmelnytskyi, Ukraine, 29013	646
Kryvyi Rih State Pedagogical University	KRSPU	54, Gagarin Ave., Kryvyi Rih, Dnipropetrovsk region, Ukraine, 50086	1532
National Pedagogical Dragomanov University	NPDU	9, Pyrohov Str., Kyiv, Ukraine, 01601	4504
Oleksandr Dovzhenko Hlukhiv National Pedagogical University	ODHNPU	24, Kyievo-Moskovska Str., Hlukhiv, Sumy region, Ukraine, 41400	1079
Pavlo Tychyna Uman State Pedagogical University	PTUSPU	2 Sadova Str., Uman, Cherkassy region, Ukraine, 20300	4280
Poltava V. G. Korolenko National Pedagogical University	PKKNPU	2, Ostrohradskyi Str., Poltava, Ukraine, 36003	2451
South Ukrainian National Pedagogical University named after K. D. Ushynsky	SUNOUU	26, Staroportofrankivska Str., Odesa, Ukraine, 65020	1993
Sumy State Pedagogical University named after A. S. Makarenko	SSPUM	87, Romenska Str., Sumy, Ukraine, 40002	1774
T. H. Shevchenko National University “Chernihiv Collegium”	THSNUCC	53, Hetman Polubotok Str., Chernihiv, Ukraine, 14013	1319
Ternopil Volodymyr Hnatiuk National Pedagogical University	TVHNPU	2, Maxksym Kryvonis Str. Ternopil, Ukraine, 46027	2258
Ukrainian Engineering and Pedagogical Academy	UEPA	16, Universytetska Str., Kharkiv, Ukraine, 61003	1326
Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University	VMKSPU	32, Ostrozkyi Str., Vinnytsia, Ukraine, 21100	2288
Volodymyr Vynnychenko Central Ukrainian State Pedagogical University	VVCUSPU	1, Shevchenko Str., Kropyvnytskyi, Ukraine, 25006	2296

Table 1
Ukrainian Pedagogical HEIs that recruited students in 2018
Sources: official websites of Ukrainian Pedagogical HEIs[18].

[18] Berdyansk State Pedagogical University, “Maine page”, http://www.bdpu.org (accessed June 28, 2020); Bogdan Khmelnitsky Melitopol State Pedagogical University, “Maine page”, http://www.mdpu.org.ua (accessed June 28, 2020); Borys Grinchenko Kyiv University, “Maine page”, http://kubg.edu.ua (accessed June 28, 2020); Donbas State Pedagogical University, “Maine page”, http://www.slavdpu.dn.ua (accessed June 28, 2020); Drohobych Ivan Franko State Pedagogical University, “Maine page”, http://dspu.edu.ua (accessed June 28, 2020); H. S. Skovoroda Kharkiv National Pedagogical University, “Maine page”, http://www.pu.ac.kharkov.ua (accessed June 28, 2020); Hryhorii Skovoroda Pereiaslav-Khmelnytskyi State Pedagogical University, “Maine page”, http://www.phdpu.edu.ua (accessed

In Table 1, pedagogical HEIs are alphabetically listed, their legal addresses, the number of students enrolled, and sources of official information. Territorially they are located in 16 regions, including 2 in the capital of Ukraine, 2 in Zaporizhia, Sumy, and Kharkiv regions. In total, 42.6 thousand students are enrolled in pedagogical HEIs in 2018, more than half of whom have chosen to study at Kyiv (NPDU and BGKU), Kyiv region (HSPKSPU), Cherkasy region (PTUSPU), Kharkiv (HSSKNPU and UEPA), and Zaporizhia region (BSPU and BKMSPU).

Speaking about the potential of innovative HEIs, should thoroughly investigate the possibility of formalizing its components. The formalization process is to quantify those components of innovation potential that can be quantified. Based on empirical analysis, 16 indicators of innovation potential have been identified and quantified. These indicators have been able to generate and quantify, based solely on official, freely available sources of information. They can be grouped into 4 components of the HEIs innovation potential: physical capital potential, human capital potential, potential of government regulation, and higher education services market potential (Fig. 1).

Let us dwell on each component of the higher education institution's innovation potential, as shown in Fig. 1. It should be emphasized that physical capital potential and human capital potential interpret the internal environment of the organization, but potential of government regulation and higher education services market potential interpret the external environment of the organization.

The physical capital potential is formed through investments in fixed and intangible assets that are intended for direct multi-use educational and research activities. Therefore, we understand the library fund, the collection of computer hardware and the necessary software in educational and scientific activities, as well as the funding of research and development as parts of the physical capital potential of a higher education institution.

June 28, 2020); Khmelnytskyi Humanities and Pedagogical Academy, "Maine page", http://www.kgpa.km.ua (accessed June 28, 2020); Kryvyi Rih State Pedagogical University, "Maine page", https://kdpu.edu.ua (accessed June 28, 2020); National Pedagogical Dragomanov University, "Maine page", http://www.npu.edu.ua (accessed June 28, 2020); Oleksandr Dovzhenko Hlukhiv National Pedagogical University, "Maine page", http://gnpu.edu.ua (accessed June 28, 2020); Pavlo Tychyna Uman State Pedagogical University, "Maine page", https://udpu.org.ua (accessed June 28, 2020); Poltava V. G. Korolenko National Pedagogical University, "Maine page", http://pnpu.edu.ua (accessed June 28, 2020); South Ukrainian National Pedagogical University named after K. D. Ushynsky, "Maine page", http://www.pdpu.edu.ua (accessed June 28, 2020); Sumy State Pedagogical University named after A. S. Makarenko, "Maine page", http://www.sspu.sumy.ua (accessed June 28, 2020); T. H. Shevchenko National University "Chernihiv Collegium", "Maine page", http://chnpu.edu.ua (accessed June 28, 2020); Ternopil Volodymyr Hnatiuk National Pedagogical University, "Maine page", http://www.tnpu.edu.ua (accessed June 28, 2020); Ukrainian Engineering and Pedagogical Academy, "Maine page", http://www.uipa.edu.ua (accessed June 28, 2020); Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University, "Maine page", http://www.vspu.edu.ua (accessed June 28, 2020); Volodymyr Vynnychenko Central Ukrainian State Pedagogical University, "Maine page", https://www.cuspu.edu.ua (accessed June 28, 2020).

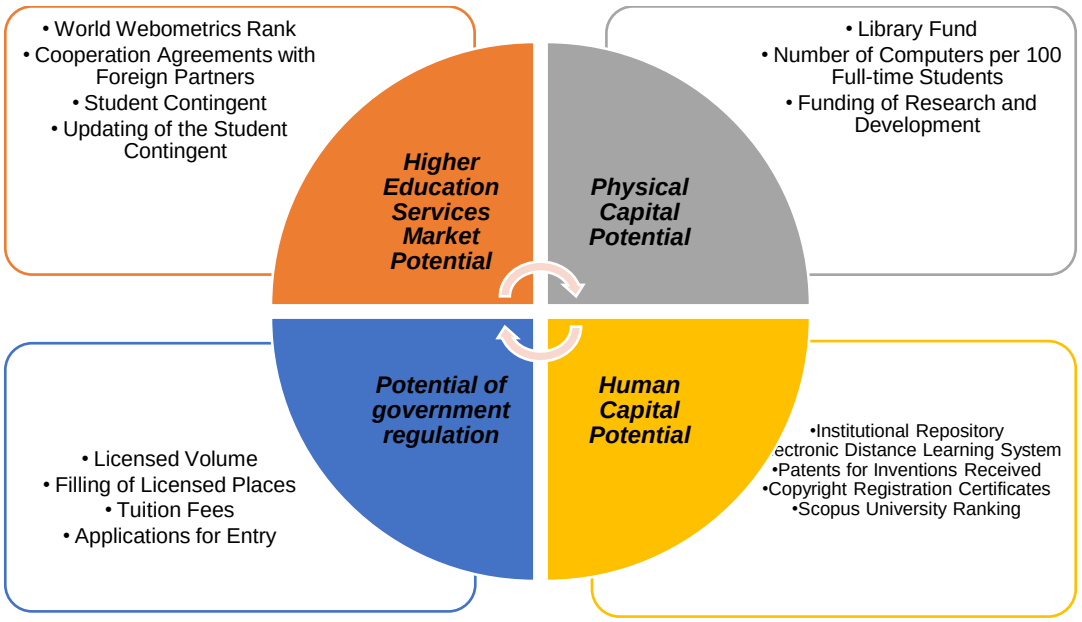

Figure 1
Functional structure of the innovation potential of higher education institution
Sources: author's own interpretation.

The human capital potential is interpreted primarily as the results of the intellectual work of the teaching staff of higher education institutions, their protection, and preservation for the development of education and science. Given this understanding of human capital potential, important areas of the teaching staff activity are working with the institutional repository and electronic distance learning system, copyright protection and patenting of inventions, as well as the publication of research in leading scientific journals, in particular, those indexed in Scopus.

Potential of government regulation is the third component of the higher education institution's innovation potential. The content of this component of the higher education institution's innovation potential lies in the benefits that it receives from the legality of its activities. Here we single out-licensing of educational programs and obtaining licensed places for training (with their filling), financing of the contractual form of training and the volume of applications submitted by applicants for entry.

Higher education services market potential includes the competitive advantages of higher education institution as a result of brand positioning, promotion of educational services, career guidance, stakeholder engagement, etc. At the same time, the adaptation behavior of HEIs in the conditions of a competitive market of higher education services regulated by the state is important for the formation of economic security[19]. Therefore, we will provide the characteristic and methodological support for formalizing the components of the innovation potential of HEIs.

[19] Biloshkurska Nataliia, "Adaptive behavior models and their role in formation of enterprise economic security", Actual Problems of Economics Vol: 114 (2010): 101–105; Biloshkurska Nataliia, Biloshkurskyi Mykola, and Omelyanenko Vitaliy, "Evaluation of Ukrainian industry innovative development with a technological progress parameter", Scientific Bulletin of Polissia Vol: 1 part 2 (2018): 23–28, https://doi.org/10.25140/2410-9576-2018-2-1(13)-23-28.

1. *Physical capital potential:*

1.1. Library Fund (copies of books, including electronic ones, per 1 student) – *LF*;

1.2. Number of Computers per 100 full-time students – *NC*;

1.3. The Funding of Research and Development, thousand UAH – *FRD*;

2. *Human capital potential:*

2.1. Documents Downloaded to Institutional Repository (units per 1 full-time lecturer) – *DDIR*;

2.2. The Share of Disciplines Placed in the Electronic Distance Learning System, % – *EDLS*;

2.3. Number of Patents for Inventions received in 2018 – *NPI*;

2.4. Number of Copyright Registration Certificates received in 2018 – *NCRC*;

2.5. Scopus University Ranking – *SUR*[20];

3. *Potential outcomes of government regulation:*

3.1. Licensed Volume – number of places for entry under the Ministry's license – *LV*;

3.2. Filling of Licensed Places (ratio of the number of students enrolled in the first year to the licensed volume), % – *FLP*;

3.3. Tuition Fees (first year bachelor, full time), UAH – *TF*;

3.4. The Total Number of Applications for Entry – *NAE*;

4. *Potential of the higher education services market condition:*

4.1. World Webometrics Rank – *WWR*[21];

4.2. The Total Number of Cooperation Agreements with Foreign Partners – *NCAF*;

4.3. Student Contingent (total number of students who study in higher education institution), persons – *SC*;

4.4. Updating of the Student Contingent (ratio of enrolled students in the first year to the Student Contingent), % – *USC*.

All the proposed indicators, with the exception of tuition fees, are stimulants, which means that their growth increases the efficiency of managing innovative potential. Tuition fees are a disincentive, so a reduction in its volume is considered positive. Let's carry out the necessary calculations of the proposed indicators for the group studied Ukrainian pedagogical HEIs and form Table 2.

HEIs	***LF***	***NC***	***FRD***	***DDIR***	***EDLS***	***NPI***	***NCRC***	***SUR***	***LV***	***FLP***	***TF***	***NAE***	***WWR***	***NCAF***	***SC***	***USC***
BSPU	49.2	15.3	1284.6	0	60	0	0	94	11393	19.1	10400	2486	11750	125	5537	39.3
BKMSPU	98.4	12.4	1995.3	13.2	100	3	71	140	4655	37.7	10000	4805	10190	42	4166	42.2
BGKU	29.8	13.1	2300.0	23.6	80	0	57	139	5187	59.9	20000	18352	5974	71	9043	34.3
DSPU	151.0	18.4	76.7	0	70	0	1	127	4257	34.6	18000	3260	16309	25	3776	39.1
DIFSPU	146.1	10.0	2983.2	0	60	2	0	42	3936	47.0	17000	4923	17747	51	5024	36.8

[20] Osvita.ua, "Scopus University Rankings 2019", http://osvita.ua/vnz/rating/64398 (accessed June 28, 2020).

[21] Sergiy Kvitka; Galina Starushenko; Viktor Koval; Hanna Deforzh and Olha Prokopenko, "Marketing of Ukrainian higher educational institutions representation based on modeling of Webometrics Ranking", Marketing and Management of Innovations Vol: 3 (2019): 60–72, http://doi.org/10.21272/mmi.2019.3-05.

HSPKSPU	103.0	18.2	315.5	2.9	100	16	14	81	8664	27.6	13460	7896	8040	35	6335	37.7
HSSKNPU	72.8	15.5	204.8	9.6	80	0	0	167	6614	31.9	14000	5565	13488	21	5340	39.5
KHPA	65.2	17.3	0	0	54	0	0	167	1627	39.7	26000	1367	19385	14	1915	33.7
KRSPU	144.9	6.2	752.2	8.7	50	0	0	91	3529	43.4	17000	3512	9429	30	4216	36.3
NPDU	82.8	15.1	5208.8	17.7	100	2	0	105	11488	39.2	19000	24133	4318	150	13997	32.2
ODHNPU	145.0	6.5	604.8	5.9	60	0	0	167	2321	46.5	15000	2201	13323	19	2482	43.5
PTUSPU	47.9	11.2	606.0	19.8	100	14	123	116	11172	38.3	10800	10483	11553	57	10252	41.7
PKKNPU	86.6	8.6	760.8	32.8	62	1	38	130	5722	42.8	11900	5959	7833	30	6462	37.9
SUNOUU	40.8	11.9	2024.8	5.2	90	1	55	51	4960	40.2	13000	5884	13844	23	8412	23.7
SSPUM	205.4	12.7	513.8	20.0	60	0	3	109	6106	29.1	10400	4857	15130	34	4488	39.5
THSNUCC	146.8	9.2	439.6	8.5	90	16	0	167	2764	47.7	14100	3492	11535	40	3471	38.0
TVHNPU	106.8	17.8	1383.6	21.6	95	4	5	57	5810	38.9	19000	6461	11414	47	8544	26.4
UEPA	187.8	17.7	1080.3	23.9	100	69	61	107	3335	39.8	12000	2287	8284	33	5887	22.5
VMKSPU	101.7	12.2	1590.2	10.6	80	1	3	157	5014	45.6	14000	7711	14237	46	5901	38.8
VVCUSPU	192.7	26.6	97.0	9.4	70	0	64	111	5133	44.7	13000	4002	14361	28	4519	50.8

Table 2
Indicators of innovative potential of Ukrainian pedagogical HEIs (as of early 2019)
Sources: official websites of Ukrainian Pedagogical HEIs

The data in Table 2 are fundamental to the statistical evaluation of the effectiveness of managing the innovation potential of HEIs. We have thoroughly investigated the components of the higher education institution's innovation potential and implemented solutions to the problem of their formalization. This made it possible to quantify the main components of the innovation potential by calculating the 16 indicators listed above. It should be noted that in the case of assessing the innovative potential of a single higher education institution, it is sufficient to calculate the proposed indicators in dynamics for a few years and to draw conclusions. If the task is to assess the innovative potential of a group of HEIs (see Tables 1 and 2), it is necessary to use complex analytical tools for statistical evaluation[22].

[22] Nataliia Biloshkurska, "Marketing research of pricing factors in a competitive market", Marketing and Management of Innovations Vol: 1 (2015): 24–31; Nataliia Biloshkurska; Mykola Biloshkurskyi and Ludmyla Chvertko, "Influence of the security market condition on the collective investment development", Scientific Bulletin of Polissia Vol: 3 part 2 (2017): 138–142, https://doi.org/10.25140/2410-9576-2017-2-3(11)-138-142; Nataliia Biloshkurska; Mykola Biloshkurskyi and Roman Kravchenko, "Marketing analysis of the strategic competitiveness of regional establishments of higher education", Economies' Horizons Vol: 2 (2017): 25–30, https://doi.org/10.31499/2616-5236.2(3).2017.128097; Olha Prokopenko; Nataliia Biloshkurska; Mykola Biloshkurskyi and Vitaliy Omelyanenko, "The role of banks in national innovation system: general strategical analytics", Financial and Credit Activity – Problems of Theory and Practice, Vol: 17 num 1 (2019): 380–394, https://doi.org/10.18371/fcaptp.v3i30.179455.

The sum of places method. Given the data in Table 2, it is possible to rank investigated HEIs by the level of innovation potential management using the sum of places method. It is advisable to apply this method to benchmarking, for example, group of HEIs with a large number of indicators without giving them priority and importance. First, we define a stimulant or disincentives is an indicator. For each educational institution, by ranking, we determine the place by the numerical value of this indicator. The first place is occupied by the institution with the best indicator value, the last place is taken by the institution with the worst indicator value. In the final stage, we summarize all the places that are assigned to each higher education institution. Ranking of HEIs is based on the principle of minimum:

$$\sum_{i=1}^{n} P_{ij} \rightarrow \min, \quad (1)$$

where P_{ij} is the place of i-th higher education institution by j-th indicator, $j = \overline{1; m}$.

Based on equation (1), the first ranked place will be occupied by the higher education institution with the lowest sum of places, and the last ranking place will be taken by the higher education institution with the largest sum of places. This complex method of comparative analysis is available for use in retrospect, but the results obtained cannot be used in strategic management.

In order to solve the problem of strategic management of the higher education institution's innovation potential, it is necessary to use the methodological apparatus of correlation and regression analysis. Within the framework of correlation and regression analysis, it is possible to solve the strategic problem of innovative potential influence on the development of HEIs. To this end, all 16 indicators of innovation potential (see Table 2) should be taken as predictor variables and the number of enrolled students (*NES*) should be taken as the response variable. It is the number of enrolled students that is the most successful indicator of the development of a higher education institution, as it expresses the results of all areas of its activity and notifies the development for at least 4 coming years.

Correlation Analysis. Multicollinearity Test. Procedurally, correlation analysis is performed by constructing a correlation matrix with the application of statistical data processing software (e.g. Excel), which places paired correlation coefficients between all predictor variables. Using the pair correlation coefficients, a test for the presence of multicollinearity is performed. Determine the presence or absence of multicollinearity between the predictor variable of the model by paired correlation coefficients. We must determine the criterion according to which we decide on the absence or presence of multicollinearity. The predictor variables without multicollinearity will be introduced into the multifactorial model. The main feature of multicollinearity between the predictor variables is the significant value of the paired correlation coefficient, which signals a stochastic high-density relationship. The significance or reliability of this relationship is decided on the basis of the observed F-test, calculated by the equation:

$$F = \frac{R^2}{1 - R^2} \cdot \frac{n - m - 1}{m}, \quad (2)$$

where R is the correlation coefficient;
n is the number of values of the observed indicators;
m is the number of predictive variables in the model.

The observed F-test value is compared with the critical value calculated for the significance level α = 0,05 and the degrees of freedom $k_1 = m$ & $k_2 = n – m – 1$. In our case, $k_1 = 1$ and $k_2 = 20 – 1 – 1 = 18$. Using the Excel statistical function "F.INV", we find the critical value of the F-test: F.INV(0.95;1;18) = 4.41. Therefore, all values of the paired correlation coefficient for which the observed F-test values will be less than 4.41 will indicate a statistically insignificant relationship between the predictor variables that will be introduced into the model, and therefore we can assume that there is no multicollinearity between them. Find the maximum value of the correlation coefficient pair for which will be implemented this requirement, solving equations with one unknown:

$$4.41 = \frac{R^2}{1 – R^2} \cdot \frac{20 – 1 – 1}{1} = \frac{18R^2}{1 – R^2};$$
$$18R^2 = 4.41\left(1 – R^2\right); \; 18R^2 = 4.41 – 4.41R^2;$$
$$22.41R^2 = 4.41; \; R^2 = 0.197;$$
$$R = \pm\sqrt{0.197} = \pm 0.444. \quad (3)$$

Consequently, no multicollinearity between the predictor variable considers when executed condition:

$$R \in [-0.444; \; 0.444]. \quad (4)$$

Regression Analysis. Regression analysis is realized through the introduction of predictor variables between which there is no multicollinearity into the multiple linear regression model. Procedurally, the main task of regression analysis is to calculate regression coefficients (regression equation parameters) using statistical data processing software (e.g. Excel) using the general equation:

$$y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_i X_i + \varepsilon,$$

where y is the response variable;

$X_1, X_2, \ldots, X_i$ are the predictor variables, $i = \overline{1; n}$;
$\beta_1, \beta_2, \ldots, \beta_i$ are the regression coefficients (parameters) of a multiple linear regression model which show how many units change response variable, with the growth of corresponding i-th predictor variable to 1 unit;
β_0 is the intercept;
ε is the error term or disturbance term.

The last indicator to be calculated in the study of the statistical impact of innovation potential on the higher education institution development will be the elasticity coefficient. The elasticity coefficient is, in essence, a percentage change in the response variable with a predictor variable increase of 1%.

It is also necessary to calculate the elasticity coefficient ($E_{(X_i)}$) of the response variable by the i-th predictor variable to the equation:

$$E_{(X_i)}=\beta_i \frac{\overline{X_i}}{y(\overline{X_i})}$$

where β_i is a regression coefficient that shows how many units the response variable changes as the *i*-th predictor variable increases by 1 unit;

$\overline{X_i}$ is the average of the *i*-th predictor variable;
$y(\overline{X_i})$ – is the value of the response variable, calculated by the regression equation (see equation (5) in which takes the average value of the *i*-th predictor variable, with those remaining predictor variables that do not change.

Results

According to the table 2, using the equation (1), we rank the studied HEIs innovation potential management ranking by the sum of places (Table 3).

HEIs	*LF*	*NC*	*FRD*	*DDIR*	*EDLS*	*NPI*	*NCRC*	*SUR*	*LV*	*FLP*	*TF*	*NAE*	*WWR*	*NCAF*	*SC*	*USC*	*Sum of places*	*Rank*
BSPU	17	8	8	17	7	8	12	6	2	20	2	17	11	2	10	6	153	12
BKMSPU	12	12	5	8	1	5	2	15	13	15	1	12	7	8	16	3	135	8
BGKU	20	10	3	3	4	8	5	14	9	1	14	2	2	3	3	14	115	3
DSPU	4	2	19	17	5	8	11	12	14	16	12	16	18	15	17	7	193	18
DIFSPU	6	16	2	17	7	6	12	1	15	3	11	10	19	5	12	12	154	13
HSPKSPU	10	3	16	16	1	2	8	4	4	19	7	4	4	10	7	11	126	5
HSSKNPU	15	7	17	10	4	8	12	17	5	17	8	9	13	17	11	5	175	16
KHPA	16	6	20	17	8	8	12	17	20	11	15	20	20	19	20	15	244	20
KRSPU	8	20	11	12	9	8	12	5	16	7	11	14	6	13	15	13	180	17
NPDU	14	9	1	7	1	6	12	7	1	12	13	1	1	1	1	16	103	1
ODHNPU	7	19	13	14	7	8	12	17	19	4	10	19	12	18	19	2	200	19
PTUSPU	18	15	12	6	1	3	1	11	3	14	3	3	10	4	2	4	110	2
PKKNPU	13	18	10	1	6	7	7	13	8	8	4	7	3	13	6	10	134	7
SUNOUU	19	14	4	15	3	7	6	2	12	9	6	8	14	16	5	18	158	14
SSPUM	1	11	14	5	7	8	10	9	6	18	2	11	17	11	14	5	149	11
THSNUCC	5	17	15	13	3	2	12	17	18	2	9	15	9	9	18	9	173	15
TVHNPU	9	4	7	4	2	4	9	3	7	13	13	6	8	6	4	17	116	4
UEPA	3	5	9	2	1	1	4	8	17	10	5	18	5	12	9	19	128	6
VMKSPU	11	13	6	9	4	7	10	16	11	5	8	5	15	7	8	8	143	10
VVCUSPU	2	1	18	11	5	8	3	10	10	6	6	13	16	14	13	1	137	9

Table 3
Ukrainian pedagogical HEIs innovation potential management ranking by the sum of places (as of early 2019)
Source: calculated by the authors

As can be seen from Table 3, NPDU scored the smallest amount of places (103), which ranked highest in the innovation potential ranking. PTUSPU with a sum of places 110 and BGKU with a sum of places 115 are among the TOP 3 best HEIs innovation potential. Group's outsiders in terms of innovative potential management are the following three Ukrainian Pedagogical HEIs: DSPU with a sum of places 193, ODHNPU with a sum of places 200, and KHPA with a sum of places 244.

Therefore, the total values obtained can be interpreted as the level of Ukrainian pedagogical HEIs innovation potential management, according to the sum of places method. As noted, the number of enrolled students can be interpreted as the development level of Ukrainian pedagogical HEIs.

Let us evaluate the impact of innovation potential on the HEIs development. For this, it is necessary to construct a graph where we take the number of enrolled students as the dependent variable, and the sum of places in terms of innovative potential obtained by HEIs as the independent variable (Fig. 2).

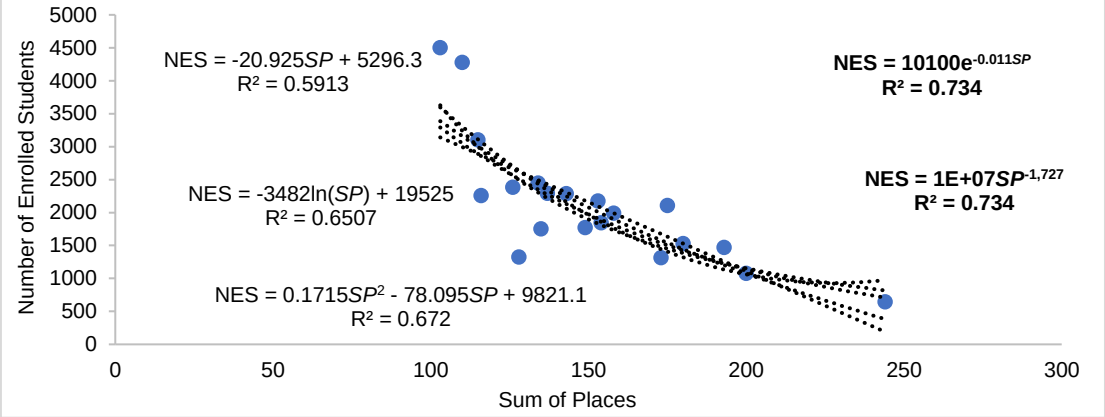

Figure 2
Functional structure of the innovation potential of higher education institution
Source: calculated by the authors

In the graph illustrated in Fig. 2, we have also constructed 5 trend lines with corresponding equations and approximation levels. All these trend models are characterized by high levels of approximation ($R^2 > 0.5$), which suggests they reliable. All of them illustrate the inverse relationship between the number of enrolled students and the sum of places that HEIs received according to Table 2. The interpretation of the linear trend equation is as follows: with the increase of the sum of places by 1 unit, the number of enrolled students decreased by 21 persons. The interpretation of the equation of power trend is as follows: with the increase of the sum of places by 1%, the number of enrolled students decreased by 1.73%.

However, this is a retrospective analysis based on factual reporting. Its results only give a vision of the situation at the beginning of 2019. But they do not provide an opportunity to assess trends in the development of innovation potential indicators, as well as to explore their complex impact on the development of Ukrainian pedagogical HEIs. Our study, which is to improve management of the higher education institution's innovative potential, requires a strategic approach and prospective analysis. It was used in the study of correlation and linear multivariate regression analysis satisfies the condition of strategic management. First, we implement regression analysis in the statistical evaluation of the management of higher education institution's innovative potential. Correlation analysis is performed using "Data Analysis" and selecting "Correlation" in Excel.

It is necessary to choose an array of data with indicators that we plan to use the predictor variables in a linear multivariate regression model. The result is a correlation matrix, which is a square matrix of size m x m, where m is the number of indicators.

The resulting correlation matrix (Table 4) is used to test for multicollinearity between the indicators that are to be introduced into the linear multivariate regression model.

Indicators	***LF***	***NC***	***FRD***	***DDIR***	***EDLS***	***NPI***	***NCRC***	***SUR***	***LV***	***FLP***	***TF***	***NAE***	***WWR***	***NCAF***	***SC***	***USC***
LF	1															
NC	0.151	1														
FRD	-0.272	-0.160	1													
DDIR	-0.011	-0.115	0.167	1												
EDLS	-0.212	0.230	0.309	0.309	1											
NPI	0.307	0.158	-0.077	0.285	**0.471**	1										
NCRC	-0.216	0.116	-0.026	0.432	**0.466**	0.313	1									
SUR	-0.041	-0.114	-0.351	0.055	-0.111	-0.063	-0.064	1								
LV	-0.422	0.167	0.345	0.152	0.357	-0.093	0.203	-0.281	1							
FLP	0.012	-0.282	0.223	0.275	-0.024	-0.024	0.193	0.203	**0.524**	1						
TF	-0.187	0.116	0.152	-0.219	-0.236	-0.237	-0.402	0.094	-0.332	0.381	1					
NAE	-0.423	0.003	**0.730**	0.398	0.436	-0.139	0.159	-0.073	**0.546**	0.273	0.216	1				
WWR	0.227	0.120	-0.427	**-0.602**	**-0.499**	-0.288	-0.250	0.061	-0.429	-0.119	0.178	**-0.632**	1			
NCAF	-0.347	0.033	**0.723**	0.099	0.219	-0.083	-0.067	-0.207	**0.735**	-0.181	-0.003	**0.662**	**-0.496**	1		
SC	**-0.466**	0.057	**0.689**	**0.474**	**0.582**	0.046	0.327	-0.376	**0.702**	0.059	0.001	**0.860**	**-0.622**	**0.657**	1	
USC	0.209	0.052	-0.343	-0.218	0.335	**-0.460**	0.049	0.413	0.091	-0.046	0.276	0.145	-0.225	-0.078	0.370	1

Table 4
Correlation matrix of indicators introduced in the model of the impact of innovation potential on the Ukrainian pedagogical HEIs development
Source: calculated by the authors

The pair correlation coefficients reported in Table 4 are tested for multicollinearity according to equation (4). Bold is a pair correlation coefficient that accurately informs the strong correlation between the indicators. That multicollinearity between these indicators necessarily present. After excluding half of the indicators (number of computers per 100 full-time students, the share of disciplines placed in the electronic distance learning system, number of patents for inventions received in 2018, licensed volume, the total number of applications for entry, World Webometrics Rank, the total number of cooperation agreements with foreign partners and student contingent) and re-using “Data Analysis” and selecting “Correlation” in Excel, we obtain a new correlation matrix (Table 5).

Indicators	***LF***	***FRD***	***DDIR***	***NCRC***	***SUR***	***FLP***	***TF***	***USC***
LF	1							
FRD	-0.272	1						
DDIR	-0.011	0.167	1					
NCRC	-0.216	-0.026	0.432	1				
SUR	-0.041	-0.351	0.055	-0.064	1			
FLP	0.012	0.223	0.275	0.193	0.203	1		
TF	-0.187	0.152	-0.219	-0.402	0.094	0.381	1	
USC	0.209	-0.343	-0.218	0.049	0.413	-0.046	-0.276	1

Table 5
Correlation matrix of indicators introduced in the model of the impact of innovation potential on the Ukrainian pedagogical HEIs development (without multicollinearity)
Source: calculated by the authors

As seen from the data presented in Table 5, the pair correlation coefficients between all predictor variables do not fall into the range of -0,444 to +0.444 (see equation (4). As a result, we can conclude that there is no multicollinearity between predictor variables. Therefore, the predictor variables of the multifactor regression model of the

innovation potential impact on the development of Ukrainian pedagogical HEIs are library fund (*LF*), the funding of research and development (*FRD*), documents downloaded to institutional repository (*DDIR*), number of copyright registration certificates (*NCRC*), Scopus University Ranking (*SUR*), filling of licensed places (*FLP*), tuition fees (*TF*), and updating of the student contingent (*USC*).

Once the response and predictor variables have been identified and selected, we begin to implement regression analysis using “Data Analysis” and selecting “Regression” in Excel. Results of regression analysis of the innovative potential impact on the development of Ukrainian pedagogical HEIs are shown in Fig. 3.

SUMMARY OUTPUT

Regression statistics	
Multiple R	0,86892367
R Square	0,755028344
Adjusted R Square	0,576867139
Standard Error	619,1208942
Observations	20

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*	*t*
Regression	8	12995441,05	1624430,131	4,237894244	0,015098127	6,329878653
Residual	11	4216417,498	383310,6817			
Total	19	17211858,55				

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*
Intercept	3,635685652	1379,222142	0,002636041	0,997943945	-3032,011782	3039,283153
LF	-5,687277428	3,368461569	-1,688390178	0,119449383	-13,10121135	1,726656497
FRD	0,389061693	0,144225531	2,69759238	0,020745803	0,07162344	0,706499947
DDIR	47,52846249	19,23795221	2,470557259	0,031090673	5,186015158	89,87090983
NCRC	6,653582697	5,803320761	1,146513	0,275910962	-6,119440178	19,42660557
SUR	-5,350817401	4,821245121	-1,109841393	0,290740291	-15,96230636	5,260671562
FLP	-3002,67314	2280,740115	-1,316534541	0,214765722	-8022,548286	2017,202007
TF	0,04820091	0,052012221	0,926722778	0,373956497	-0,066277217	0,162679037
USC	7244,667101	2786,530745	2,599887733	0,024698939	1111,554284	13377,77992

Figure 3
Results of regression analysis of the innovative potential impact on the development of Ukrainian pedagogical HEIs
Source: calculated by the authors

Based on the simulation results shown in Fig. 3, using the equation (5), we construct the linear multivariate regression equation:

$$NEC = 3.64 - 5.69LF + 0.39FRD + 47.53DDIR + 6.65NCRC - \\ - 5.35SUR - 3002.67FLP + 0.05TF + + 7244.67USC + \varepsilon. \quad (7)$$

Analyzing the regression equation given in equation (7), we conclude that it is statistically significant and reliable because it is described by high values of statistical coefficients and criteria. So, the multiple correlation coefficient is R = 0.869, indicating a high degree of connection integrity between the number of enrolled students and 8 indicators of innovation potential.

The coefficient of multiple determination $R^2 = 0.755$ means that the dynamics of the number of enrolled students to 75.5% driven by changes in factor characteristics, and other factors influence is 24.5%. The observed value of t-statistics 6.33 at critical 1.80 (T.INV (0.95;11) indicates the statistical significance of the multiple correlation coefficient. The observed F-test value 4.24 at critical 2.95 (F.INV(0.95;8;11) indicates a statistically significant stochastic relationship between the indicators entered in the model of the number of enrolled students.

The final stage of the statistical evaluation of the innovation potential impact on the development of Ukrainian pedagogical HEIs involves the calculation of elasticity coefficients according to the equation (6). The results are illustrated by the diagram in Fig. 4.

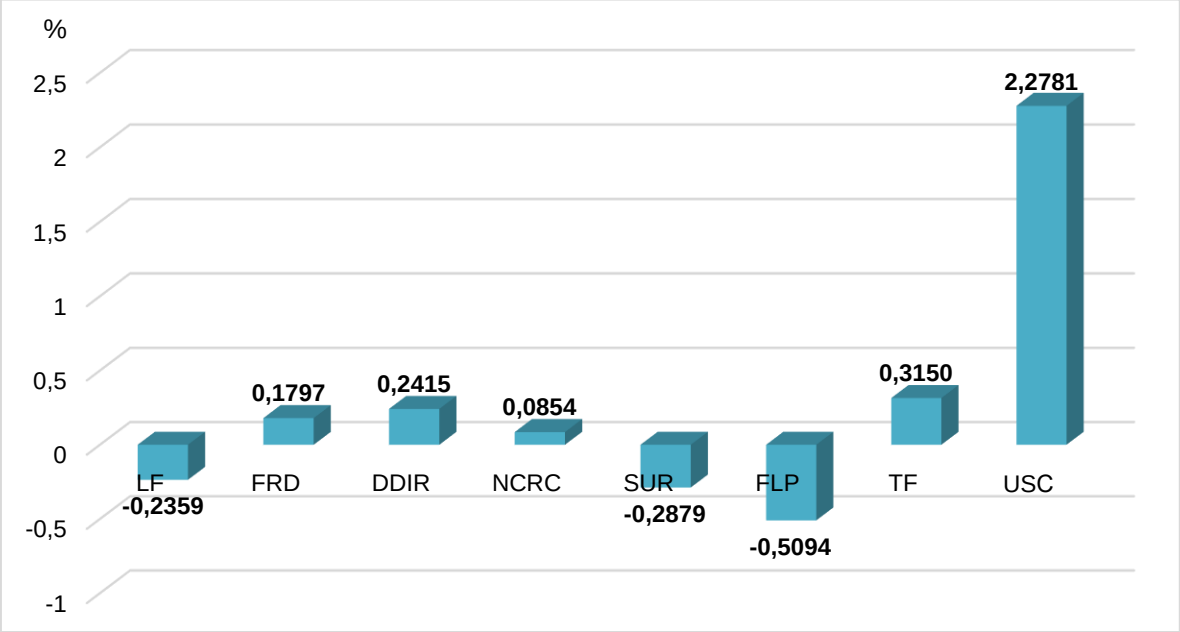

Figure 4
Elasticity coefficients of the number of enrolled students by the 8 predictor variables for Ukrainian pedagogical HEIs
Source: calculated by the authors

Following the data Fig. 4, will analyze each elasticity coefficients.

1. Library fund (copies of books, including electronic ones, per 1 student) growth by 1% leads to a 0.24% drop in the number of enrolled students. The negative impact of this indicator is explained by the fact that it increased by reducing the number of students.

2. The funding of research and development growth by 1% leads to a 0.18% growth in the number of enrolled students.

3. Documents downloaded to institutional Repository (units per 1 full-time lecturer) growth by 1% leads to a 0.24% growth in the number of enrolled students.

4. The number of copyright registration certificates received in 2018 growth by 1% leads to a 0.09% growth in the number of enrolled students.

5. Scopus University Ranking growth by 1% leads to a 0.29% drop in the number of enrolled students. In our study, it was found that the most popular HEIs had a low citation rate for teaching staff in Scopus. Therefore, there is an inverse relationship between this predictor variable and the response variable.

6. Filling of licensed places (ratio of the number of students enrolled in the first year to the licensed volume) growth by 1% leads to a 0.51% drop in the number of enrolled students. The negative impact of this indicator is explained by the fact that more successful HEIs have all the necessary facilities to expand their licensing places, so their volume is much larger than that of worse HEIs.

7. Tuition fees (first year bachelor, full time) growth by 1% leads to a 0.32% growth in the number of enrolled students. The positive impact of this indicator shows the influence of the HEIs prestige to choose applicants. Families agree to a higher contract tuition fee for a more prestigious university.

8. Updating of the student contingent (ratio of enrolled students in the first year to the student contingent) growth by 1% leads to a 2.28% growth in the number of enrolled students.

The overall growth in all predictor variables by 1% leads to an increase in the number of enrolled students to 2.07%.

Conclusions

In summary, we can draw some important conclusions.

Firstly, the problem of HEIs innovative potential formalization is solved through the systematization of relevant indicators into four components: physical capital potential, human capital potential, potential of government regulation, and higher education services market potential.

Secondly, the authors proposed the Ukrainian pedagogical HEIs innovation potential management ranking by the sum of places and proved the inverse relationship between the number of enrolled students and the HEIs sums of places.

Thirdly, for the first time, a statistical multicollinearity test was developed and implemented as part of the correlation analysis.

Fourthly, linear multifactorial regression analysis of innovation potential impact on the development of Ukrainian pedagogical HEIs was conducted, during which the priority of higher education services market potential is substantiated.

The proposed rating of the innovation potential management of HEIs, tested at the national level, is universal and can also be tested at the international level. The obtained linear multifactor model of the number of entrants according to the indicators of the HEIs innovation potential can be the basis for forecasting the development of Ukrainian pedagogical HEIs. These areas will be the prospects for further research by the authors.

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