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Higher Education System of Ukraine: Modeling of the Structural Changes

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*The **purpose of the article** is to develop a set of models and recommendations for managing structural changes in Ukraine's higher education system, based on an analysis of public funding volumes and university performance.*

The task of structurally optimizing the HES in each country centers on determining a rational balance between the potential number of applicants and students seeking higher education and the number of universities providing educational services. The selection of universities that enhance the attractiveness of the HES depends on the perspectives of key stakeholders, including national and international applicants, labor market representatives, and government agencies. Therefore, determining the required number of universities within the HES must take into account institutions' readiness for change and their ability to actively or passively adapt to modern innovations, constraints, and emerging opportunities in the global and national scientific and educational landscape, while maintaining a strong reputation among consumers of educational services.

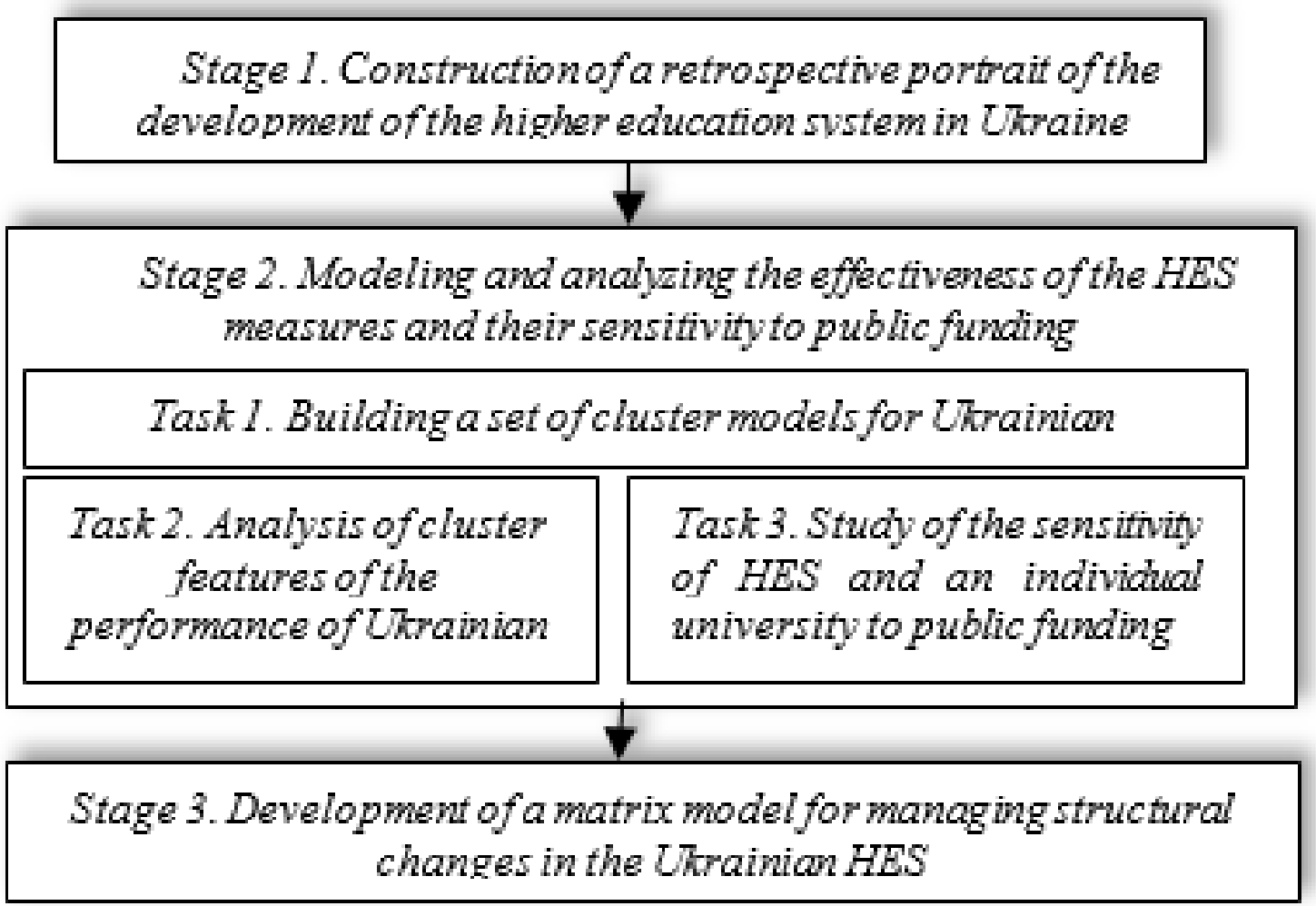
The purpose of the study led to the formulation of the following hypotheses, which form its methodology:

Hypothesis 1. The development of universities and the HES is directly dependent on public funding, which motivates universities to engage in autonomous, innovative, and entrepreneurial behavior and fosters opportunities for university development;

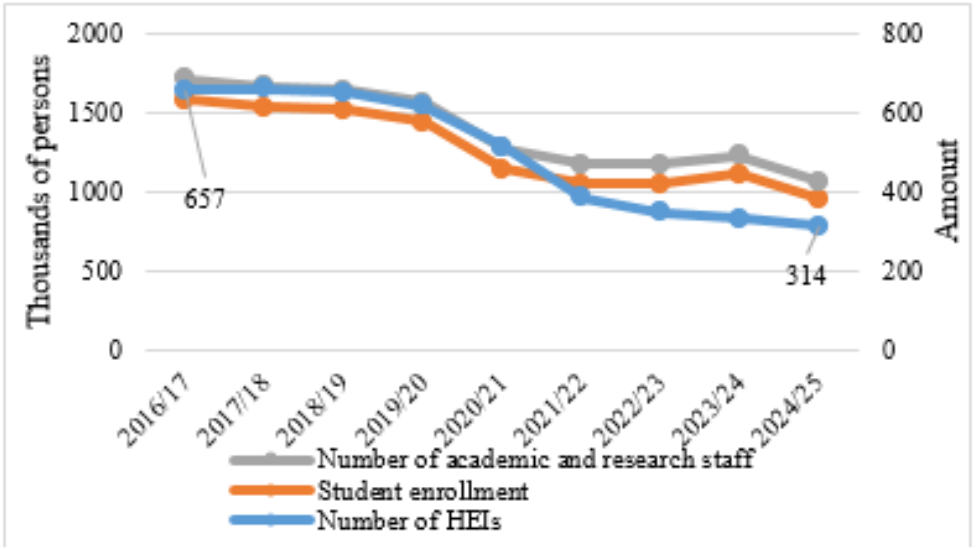
Hypothesis 2. The construction of university performance clustering models allows us to identify universities in need of restructuring.

Hypothesis 3. Managing structural changes in the HES involves optimizing the number of universities in the HES based on the use of indicators of sensitivity to public funding and university performance.

The conceptual model of the research logic, its stages, and objectives

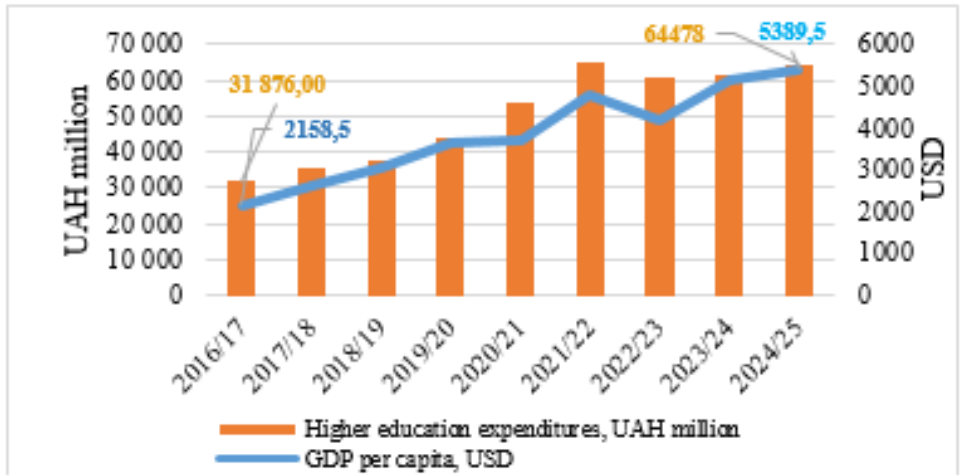


Stage 1. Constructing a retrospective portrait of the development of Ukraine's higher education system (HES)



Development trends in human resource potential and student enrollment in Ukrainian higher education: 2016–2025

Demographic crisis and decline in student enrolment. The demographic crisis that has persisted in Ukraine for over two decades, combined with external shocks in 2020 and 2022–2025, has led to a radical reduction in the student population. Over the analysed period, the total number of students in HEIs decreased from 1,587 thousand to 956 thousand, representing a decline of nearly 40 %, with the most intensive drop occurring between 2020 and 2025.



Higher education funding and GDP per capita dynamics in Ukraine: 2016–2025

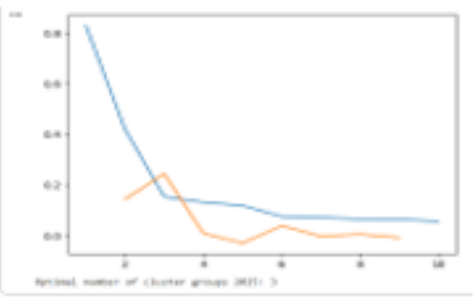
Growth in state funding amid a reduction in student numbers. Increased public funding, coupled with a decline in the number of students and universities in the country, has significantly expanded the volume of resources allocated to HEIs. Public spending per student has increased 3.36-fold (from UAH 20,000 to UAH 67,000), while spending per university has risen fourfold (from UAH 48 million to UAH 205 million). The average number of students per university has increased by 26% (from 2,400 to 3,000), reflecting the positive effects of the consolidation of university education.

Stage 2. Modeling and analyzing the effectiveness of the HES measures and their sensitivity to public funding

Building a set of cluster models for Ukrainian universities (task 1).

```
last25 = data_linkage25[-10:, 2]
last_rev25 = last25[::-1]
idxs25 = np.arange(1, len(last25) + 1)
plt.plot(idxs25, last_rev25)

acceleration25 = np.diff(last25, 2)
acceleration_rev25 = acceleration25[::-1]
plt.plot(idxs25[:-2] + 1, acceleration_rev25)
plt.show()
k25 = acceleration_rev25.argmax() + 2
print(f"Optimal number of cluster groups 2025: {k25}")
```



Determining the optimal number of cluster groups

Year	HEI Performance Cluster		
	High level	Moderate level	Low level
2020	Lviv Univer-sity, NUBiP of Ukraine, NTU "KhPI" NAU, Karazin Univer-sity, SumDU	NU "Zaporizhzhia Polytechnic", UzhNU, NURE, CHNU, Dnipro University of Technology, KNUBA, DNU, KHAI, LNTU, Lesya Ukrainka EENU, NUWEE, SNAU, NUFT, Odesa Polytec-hnic, National University of Shipbuilding, PNU, UDU, KNUCA, O.M. Beketov NUUEKh, KNUTE, IFNTUOG, Pavlo Tychyna USPU, ZNU, Kryvyi Rih National University, KNEU, LTSNU, NLU, VNTU, UHSP, TSUE, BTNAU, CPNU, NTU, KNUTD, KhNU, NaUKMA, PSACEA, TNTU, DIIT, KhNAHU	ONU I.I. Mechnikova, Uman NUH, DSAEU, OSACEA, V. Dahl EUNU, UkrSURT, TNP, RSHU, TSATU, PoltNTU, PDAU, ZNAU, ChNU, NMetAU, ONAFT, VSPU, LVET, PSTU, DDPU, CUSU, DDPU, KPNU, CNTU, T.H. Shev-chenko NU "Chernihiv Colehium", MNAU, ZSTU, USUCT, KSU, KrNU, VNAU, KDPU, Vasyl' Stus DonNU, ChSTU, KhNTUA, PMBSNU, ONMU, LNAU, HNPU named after G. S. Skovoroda, NUUPES, MDPU, SUMDPU, NLTU, PDATU, KhNUE, NUOMA, KSTUCA, NU "OLA", DNTU, DSEA, PNPU, DSTU, KSAEU, SUNPU, BSPU, KhNTU, DSPU, KNLU, Ivan Bobersky LC UPC, V.O. Sukhomlynskyi MNU, Oleksandr Dovzhenko HNPU, KHNAU, MU, NaUOA, UEPA, O.S. Popov ONAT, KhSAC, Banking University, KhGZVA, SUT, SUIT, OSENU, UCF, OSAU, LA NAU, HIFL, ONEU, KSMA, HDUHT, DonNACEA, ISUH, DonNUET, PSAPCS, MSU, DonSUM, SS NUBiP of Ukraine "Berezhany Agrotechnical Institute", KMI NMetAU, VTEI, OSATRQ, SS NUBiP of Ukraine "Nizhyn Agrotechnical Institute", LIET, ChITE SUTE, AMI NUOMA, KREI of State HEI KNEU named after Vadym Hetman, KITE KNUTE, OIE of KNUTE, UITE SUTE
2025	NUBiP of Ukraine, Lviv Univer-sity, NTU "KhPI", KAI, Karazin Univer-sity USUST, SumDU	NURE, KNUBA, CHNU, UzhNU, KHAI, Dnipro University of Technology, VNU, NU"Zaporizhzhia Polytechnic", DBTU, PNU, Odesa Polytechnic, DNU, O.M. Beketov NUUEKh, ZNU, National University of Shipbuilding, LNTU, KhNAHU, NUWEE, SNAU, TNPU, IFNTUOG, VNTU, Dragomanov Ukrainian State University, TSATU, KhNU, PoltNTU, NaUKMA, MNAU, CPNU, ZSTU	NLU, KNUCA, SUTE, NUFT, ONU I.I. Mechnikova, Zhytomyr Ivan Franko State University, VSPU, WUNU, LVET, KNEU, KNUTD, KhNUE, PDAU, RSHU, Pavlo Tychyna USPU, DSAEU, ChNU, NTU, HNPU named after G. S. Skovo-roda, NUUPES, TNTU, OSACEA, BTNAU, LSUPC, Kryvyi Rih National University, Uman NUH, V. Dahl EUNU, SUMDPU, CNTU, PNPU, NLTU, DDPU, LTSNU, LNUP, KSU, PMBSNU, VNAU, Polissia National University, T.H. Shev-chenko NU "Chernihiv Colehium", NUOMA, ONTU, KPNU, MDPU, CUSU, UHSP, KDPU, SUNPU, UkrSURT, SUICT, DSTU, KrNU, KhSAC, NU "OLA", KSAEU, ChSTU, HEI «Podillia State University», KhNTU, ONMU, BSPU, Oleksandr Dovzhenko HNPU, KNLU, PSTU, USFA, SUIT, MU, DSPU, NMGSU, UCF, SUITT, DSEA, Vasyl' Stus DonNU, OSAU, DNTU, PSAPCS, KSMA, NaUOA, MSU, V. I. Vernadsky Taurida National Univer-sity, ISUH, SUET, ONEU, SS NUBiP of Ukraine "Berezhany Agrotechnical Institute", HIFL, SS NUBiP of Ukraine "Nizhyn Agrotechnical Institute", DonNACEA, VITE SUTE, ChITE SUTE, UITE SUTE

Stage 2. Modeling and analyzing the effectiveness of the HES measures and their sensitivity to public funding

Building a set of cluster models for Ukrainian universities (task 1).

Distribution of universities by cluster groups

Year	HEI's number	HEI Performance Cluster		
		High level, number|%	*Moderate level number/ %*	*Less level, Number/ %*
2020	146	6/4.1 %	40/27.4 %	100/68.5 %
2021	144	7/4.9 %	51/35.4 %	86/59.7%
2022	136	6/4.4 %	34/25.0 %	96/70.6 %
2024	132	7/5.3%	31/23.5 %	94/71.2 %
2025	125	7/5.6 %	30/24 %	88/70.4 %

TYPE REPRESENTATIVES OF CLUSTER GROUPS PERFORMANCE LEVELS OF UKRAINIAN HEIS FOR 2020-2025

Year	HEI Performance Cluster		
	High level	*Moderate level*	*Low level*
2020	National Technical University «Kharkiv Polytechnic Institute» (NTU "KhPI")	Vasyl Stefanyk Precarpathian National University (PNU)	Kherson State Agricultural University (KSAEU)
2021	National Aviation University (NAU)	Ternopil Volodymyr Hnatiuk National Pedagogical University (TNPU)	Mariupol State University (MU)
2022	National Aviation University (NAU)	Odesa National Polytechnic University (Odesa Polytechnic)	Kherson state agrarian and economic university (KSAEU)
2024	National Technical University «Kharkiv Polytechnic Institute» (NTU "KhPI")	Ivano-Frankivsk National Technical University of Oil and Gas (IFNTUOG)	Kryvyi Rih State Pedagogical University (KDPU)
2025	V. N. Karazin Kharkiv National University (Karazin University)	Ternopil Volodymyr Hnatiuk National Pedagogical University (TNPU)	Higher educational institution «Podillia State University» (HEI «Podillia State University»)

Stage 2. Modeling and analyzing the effectiveness of the HES measures and their sensitivity to public funding

Analysis of cluster-specific features of the performance efficiency of Ukrainian universities (task 2).

PERFORMANCE INDICATORS OF UNIVERSITIES

Cluster Representative	State Funding	Student Enrollment	Integrated Performance Indicator
2025			
NTU "KPI"	1393496466	16714	72157.80
NULP	1069709924	15509	63016.93
1 cluster	413584 920	7257	25081.60
2 cluster	166 061582	3467	10201.58
3 cluster	55 822 890	1050	3040.85
2024			
NTU "KPI"	1530870607	18339	68824.0
NULP	980069399	14578	56636.7
1 cluster	496586702	8253	28301.60
2 cluster	154833001	3052	9722.50
3 cluster	80623696	1726	3058.50
2022			
NTU "KPI"	1643256499	17910	59609.57
NULP	1127696887	12903	45772.99
1 cluster	566896284	7742	22544.27
2 cluster	250334399	3103	7787.93
3 cluster	66829820	1710	2618.42
2020			
NTU "KPI"	1116254144	17400	59581.71
NULP	677729200	12274	39604.21
1 cluster	327933800	6546	20496.14
2 cluster	112971200	3787	6761.23
3 cluster	44048000	1455	2209.84

Stage 2. Modeling and analyzing the effectiveness of the HES measures and their sensitivity to public funding

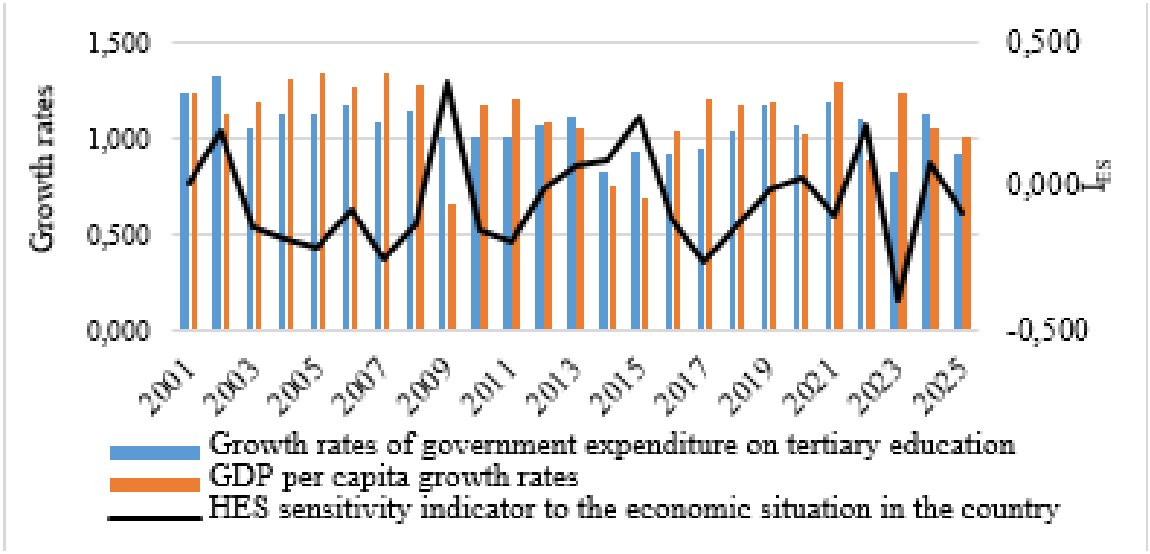
Study of the sensitivity of HES and an individual university to state funding (task 3).

Economic situation in the country (GDP per capita)

State support for HES (% of budget expenditures on higher education)

State support for the university (amount of state funding)

Model of the influence of the economic situation in the country on state support for a specific HEI



Dynamics of HES sensitivity indicators to the economic situation in the country

Indicator of the sensitivity of HEIs to public funding for 2020-2025

Name HEI's	Indicator of the sensitivity of HEIs to public funding					
	2020	*2021*	*2022*	*2023*	*2024*	*2025*
Highly sensitive						
PNU	0,05	0,06	0,05	0,00	0,12	0,19
TNPU	-0,06	0,17	0,10	-0,05	0,12	0,11
NULP	0,05	0,11	0,08	-0,13	0,19	0,11
Moderately sensitive						
NTU "KPI"	0,02	0,04	0,03	0,05	-0,07	-0,01
KSAEU	0,00	0,105	0,023	0,00	0,01	0,05
NTU "KhPI"	0,07	0,26	-0,26	0,09	0,09	-0,01
Karazin University	0,09	0,00	0,09	-0,09	0,41	-0,03
IFNTUOG	*0,01*	-0,04	*0,14*	*-0,09*	*0,09*	*0,07*
Weakly sensitive						
Odesa Polytechnic	-0,04	0,17	-0,01	-0,06	-0,04	-0,01
NAU	0,03	-0,36	0,08	0,36	-0,02	-0,01
KDPU	-0,02	0,11	-0,08	0,06	-0,12	-0,05
HEI «Podillia State niversity»	0,00	-0,09	0,06	-0,1	0,12	-0,07
MU	0,04	0,48	-0,01	-0,03	-0,29	-0,12

Stage 3. Development of a matrix model for managing structural changes in the Ukrainian HES.

Matrix Model for Identifying University Attractiveness within the Higher Education System

High performance with low sensitivity to public funding (1)	High performance with moderate sensitivity to public funding (2)	High performance with high sensitivity to public funding (3)
Moderate performance with low sensitivity to public funding (4)	Moderate performance with moderate sensitivity to public funding (5)	Moderate performance with high sensitivity to public funding (6)
Low performance with low sensitivity to public funding (7)	Low performance with moderate sensitivity to public funding (8)	Low performance with high sensitivity to public funding (9)

Conclusion

1. Deep structural transformation of higher education: The higher education system has shifted from stability to a rapid decline in the number of universities and students. This process is driven by a demographic crisis, the COVID-19 pandemic, and the full-scale Russian invasion in 2022.

2. Optimization and concentration of state funding: Reducing the network of higher education institutions (HEIs) while maintaining a stable state budget, combined with the implementation of transparent, formula-based funding mechanisms, has allowed for increased financial support for major research and innovation-oriented universities.

3. Critical imbalance and clustering of HEIs: A significant gap has been identified between the leading institutions (Igor Sikorsky Kyiv Polytechnic Institute and Lviv Polytechnic National University) and the majority of other establishments. Approximately 68% of HEIs fall into a "weak" cluster characterized by low efficiency, necessitating radical restructuring to meet the demands of the digital economy.

4. Vulnerability to crises and a strategic matrix: An analysis covering the period from 2001 to 2025 reveals that HEIs are highly susceptible to economic fluctuations, largely due to the absence of a sustainable funding strategy. A university positioning matrix—based on efficiency and sensitivity to state support—has been developed to serve as a foundation for management decision-making and sector-wide reform..

Thank you for attention