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Kalenyuk I.
Professor, Doctor of Economics,
Kyiv National Economic University named After Vadym Hetman, Ukraine;
e-mail: kalenuk@ukr.net; ORCID ID: 0000-0003-1807-2849
Tsymbal L.
Professor, Doctor of Economics,
Professor of Department of International Economy,
Kyiv National Economic University Named After Vadym Hetman, Ukraine;
e-mail: l.tsimbal@ukr.net; ORCID ID: 0000-0002-0873-9227

THE IMPACT OF INTELLECTUAL FACTORS IN ECONOMIC DEVELOPMENT OF A COUNTRY: A CLUSTER ANALYSIS

Abstract. The engine for the development of countries is the accumulation and use of intellectual resources. At the same time, there is considerable scientific interest in the question of which intellectual factors are key to ensuring the development of different countries. The purpose of the analysis is to identify the relationship between resource and performance indicators of intellectualization and GDP dynamics of the country. The resource indicators include: human; financial; intellectual. The following set of indicators relates to the results of intellectual activity already obtained, which should be divided into educational and scientific ones; infrastructure; technological.

A cluster analysis of the countries characterized by decisive development trends was made in order to identify and summarize existing dependencies. In total, 44 countries were selected for the study, which are rather heterogeneous in terms of their socio-economic development and geopolitical position.The econometric analysis identified 3 groups of countries characterized by high (cluster 1), medium (cluster 2) and low (cluster 3) GDP per capita during 2005—2015. The 4th Cluster includes rapidly developing Asian emerging countries — China, Hong Kong, Singapore, India, and the Republic of Korea.

The economic modelling of impact of resource and resulting factors on the level of economic development is carried out separately for each cluster. As a result of the simulations, the following regularities were revealed for each cluster. For first cluster countries the most significant impact on GDP growth is exerted by the government's expenditures on education and the research staff growth. For the second cluster countries growth in expenditures on education by 1% leads to a 1% increase in GDP. The third cluster countries are experiencing a significant positive impact from rising expenditures on education in general and on higher education in particular. The fourth cluster countries are experiencing a significant positive impact from the increase in research staff and the increase in public expenditures on higher education. Characteric of intelligent models of countries of different clusters allows to make realistic prognostic scenarios of their development, taking into account both changes of separate components of model, and efficiency of various economic measures and tools.

Keywords: intellectual leadership, leadership, knowledge economy, intellect, human capital, assessment of intellectual leadership.

JEL Classification I23, I25

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Каленюк І.
професор, доктор економічних наук
Київський національний економічний університет імені Вадима Гетьмана, Україна;
e-mail: kalenuk@ukr.net; ORCID ID: 0000-0003-1807-2849
Цимбал Л.
професор, доктор економічних наук, професор кафедри міжнародної економіки
Київського національного економічного університету імені Вадима Гетьмана, Україна;
e-mail: l.tsimbal@ukr.net; ORCID ID: 0000-0002-0873-9227

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ВПЛИВ ІНТЕЛЕКТУАЛЬНИХ ЧИННИКІВ НА ЕКОНОМІЧНИЙ РОЗВИТОК КРАЇНИ: КЛАСТЕРНИЙ АНАЛІЗ

Анотація. Рушійною силою розвитку країн є накопичення і використання інтелектуальних ресурсів. Водночас значний науковий інтерес викликає питання про те, які інтелектуальні фактории є ключовими для забезпечення розвитку різних країн. Метою аналізу є виявлення взаємозв’язку між ресурсними та результативними показниками інтелектуалізації та динамікою ВВП країни. До показників ресурсів належать: людина, фінансові, інтелектуальні. Ще один набір показників стосується вже отриманих результатів інтелектуальної діяльності, які поділяють на освітні і наукові, інфраструктура, технологічні.

Для виявлення та узагальнення наявних залежностей було проведено кластерний аналіз країн, що характеризуються визначальними тенденціями розвитку. Загалом, для дослідження було обрано 44 країни, які є досить неоднорідними за своїм соціально-економічним розвитком та геополітичним положенням. Економетричний аналіз виділив три групи країн, що характеризуються високим (кластер 1), середнім (кластер 2) і низьким (кластер 3) ВВП на душу населення протягом 2005—2015 років. Четвертий кластер включає азійські країни, що швидко розвиваються, — Китай, Гонконг, Сінгапур, Індія і Республіка Корея.

Економічне моделювання впливу ресурсних і результативних факторів на рівень економічного розвитку здійснено окремо для кожного кластера. У результаті моделювання були виявлені такі закономірності для кожного кластера. У країнах першого кластера найбільш значний вплив на зростання ВВП здійснюють видатки уряду на освіту і збільшення науково-дослідного персоналу. Для країн другого кластера — зростання видатків на освіту на 1 % призводить до збільшення ВВП на 1 %. Країни третього кластера відчувають значний позитивний вплив зростання витрат на освіту загалом і на вищу освіту зокрема. Країни четвертого кластера відчувають значний позитивний вплив від збільшення науково-дослідного персоналу та зростання державних видатків на вищу освіту. Характеристика інтелектуальних моделей країн різних кластерів дає змогу скласти реалістичні прогностичні сценарії їхнього розвитку, ураховуючи як зміни окремих компонентів моделі, так і ефективність різних економічних заходів та інструментів.

Формул: 19; рис.: 2; табл.: 11; бібл.: 9.

Introduction. Accelerated and active intellectualization is a common trend of modern world economic development. The axiom is that the accumulation and use of intellectual resources is the driving force (engine) for the countries’ development. It is the intellectual factors that underpin the countries’ breakthrough development and their high competitiveness basis. At the same time, a considerable scientific interest is raised by the question of what intellectual factors are important for different countries.

A cluster analysis of the countries characterized by decisive development trends was made in order to identify and summarize existing dependencies. In total, 44 countries were selected for the study, which are rather heterogeneous in terms of their socio-economic development and geopolitical position.

The purpose of the analysis is to identify the relations between resource and performance indicators for a country’s intellectualization and GDP dynamics. The resource indicators include: *human* (total number of students; number of students by level of study such as short courses, bachelor, master, doctor of philosophy, etc.; total number of students who went to study abroad; total number of students who went to study to the country; balance of inbound / outbound students; proportion of the population with higher education); *financial* (government expenditure on education (in mln units of the national currency); government expenditure on higher education (in mln units of the national currency); expenditure on higher education relative to general government expenditure (in %); education expenditure as a percentage of general government expenditure; education expenditure relative to GDP expenditure on higher education (% of GDP); *intellectual* (total number of scientists; number of scientists per 1 million of population; number of scientists per 1 thousand employees).The indicators mentioned above characterize the potential for intellectual activity.

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The following set of indicators relates to the results of intellectual activity already obtained. These results should be divided into *educational and scientific* ones (number of world-class universities; number of scientific and technical publications; number of Nobel laureates); infrastructure (number of Internet users (in % of total population); number of mobile telephony users (in persons); number of mobile telephony users (per 100 persons); number of fixed telephone communication users; number of fixed telephone communication users (per 100 persons); Secured Internet Servers; Secured Internet Servers (per 1 million of population); *technological* (technical staff in R&D; technical staff in R&D (per 1 million of population); trademark registration (residents, non-residents, and total population); high-tech exports (in $ or in % of total exports); ICT products and services (exports and imports); applications for industrial designs (from residents and non-residents); patent applications (from residents and non-residents); innovative activity of enterprises).

The methodology for identifying clusters that integrate characteristic countries is based on the results of a hierarchical agglomerative cluster analysis procedure. The process of clustering is presented in the form of a dendrogram. Figure 1 shows the dendrogram of clustering countries by GDP per capita by full-scale method, and the Euclidean distance between countries is chosen as a measure of distance. In addition, a hierarchical clustering of countries by resource and output level was conducted.

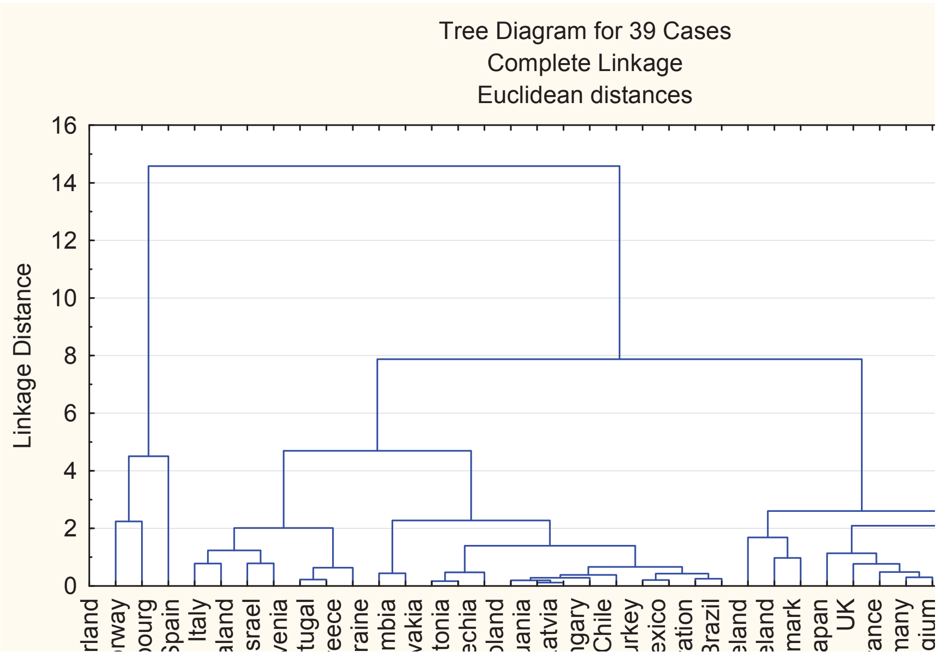

Fig. 1. **Dendrogram of hierarchical clustering of countries by GDP per capita in 2005—2015**

Note: Drawn by the authors.

Based on clustering results, we have identified 3 groups of countries characterized by high (cluster 1), medium (cluster 2) and low (cluster 3) GDP per capita values during 2005—2015. Cluster 4 includes emerging Asian emerging countries identified above — China, Hong Kong, Singapore, India, and the Republic of Korea. The composition of each cluster is given in *Table 1*.

Table 1

The list of countries in each cluster

Cluster 1	**Cluster2**
Australia;Austria; Belgium; Canada; Dania; Finland; France; Germany; Iceland; Ireland; Japan Luxembourg; Netherlands; Norway;Sweden;Switzerland; Great Britain; USA	The Czech Republic; Greece; Israel; Italy; New Zealand; Portugal; Slovenia; Spain
Cluster 3	**Cluster 4**
Brazil; Chile; Colombia; Estonia; Hungary; Latvia; Lithuania; Mexico; Poland; Russian Federation; Slovakia; Turkey; Ukraine	China; Hong Kong; India; Republic of Korea; Singapore

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The dynamics of average GDP values by clusters is presented in *Fig. 2*.

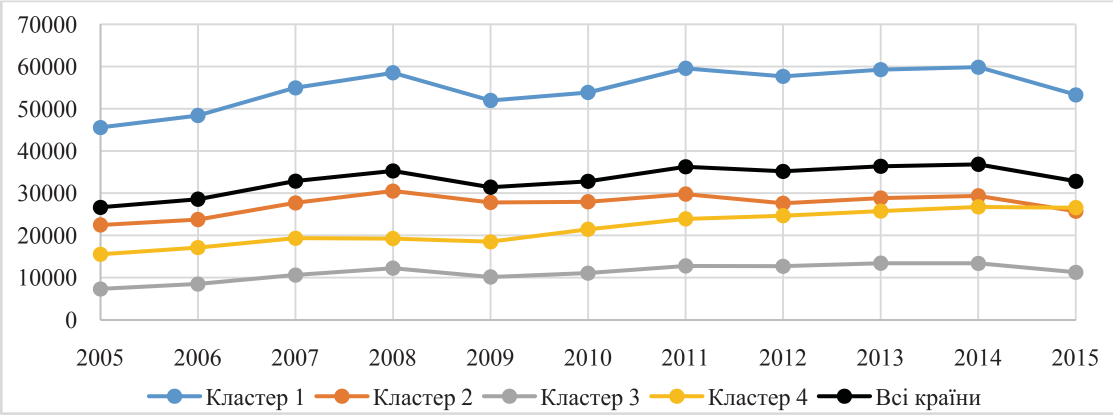

Fig. 2. **Average GDP values by clusters, $US in 2005-2015**

Note: Drawn by the authors.

We will analyze cluster averages of resource and resulting indicators (*Tabl. 2*).

Table 2

Cluster averages of resource and resulting indicators

Indicators	1 cluster	2 cluster	3 cluster	4 cluster
total_mobil	2443	1312	1414	2365
inbound_mobil.s	3870	2463	748	2444
gov_tertiary	796	336	126	205
gov_educ	3103	1361	558	715
tertiary_gov_exp	3.136	2.608	3.086	5.495
educ_gov_exp	12.611	11.573	13.625	17.880
gov_tertiary_GDP	1.422	1.119	1.117	1.152
gov_educ_GDP	5.665	4.946	4.840	3.834
Enrol_tert	45992	45471	46802	36764
Enrol_PhD	1677	1548	837	750
Enrol_short	6977	8367	9150	12960
R&D_perthousand	15	12	6	8
R&D_permillion	7515	5124	2480	3947
R&D pers	7517	5100	2482	3963

Note. Calculated by the authors.

For almost all indicators, the cluster averages differ significantly, with the exception for the number of enrolled students per 1 million of population. The highest values are observed in countries of the 1st cluster, the lowest — mostly in the countries of the 3rd cluster. Particularly noticeable differentiation between clusters exists in terms of public expenditures on education and the number of R&D staff. These indicators, by the results of modelling the impact of resource factors on the level of economic development, had a significant positive effect on GDP growth (*Tabl. 3*).

In terms of scientific potential (R&D expenditures, number of R&D researchers, publishing activity) and shares of innovatively active enterprises, countries in the 1st cluster occupy leading positions. Countries in the 4th cluster are expected to have the highest levels of high-tech exports and exports / imports of ICT goods. Similarly, the lowest values of indicators are seen for the countries of the 3rd cluster.

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Table 3

Cluster averages of resulting indicators

Indicators	1 cluster	2 cluster	3 cluster	4 cluster
Показник	1 кластер	2 кластер	3 кластер	4 кластер
mobile_sub	112	117	112	108
intern_users	81	60	50	53
hi-tech_exp_share	18	9	9	26
hi-tech_exp	1977	564	353	10260
ICT_exp	5.6	4.9	6.7	22.3
ICT_imp	8.6	7.4	9.2	15.7
design_nres	214	120	45	222
design_res	143	171	67	372
patent_nres	265	249	49	900
patent_res	371	143	53	668
trademark_nres	1111	671	491	1000
trademark_res	959	924	604	1039
research_exp	1259	460	95	513
tech_RD	4772	3511	1601	2811
articles	1553	1243	419	684
Innov	51.7	41.8	29.2	36

Note. Calculated by the authors.

Next, we will perform econometric modelling of the impact of resource and resulting indicators on the level of economic development separately for each cluster. The dummy variables characterizing the level of innovation activity of enterprises in the country — Innov_quart2, Innov_quart3, Innov_quart4 — were not used separately for modelling the impact of resulting indicators on the level of economic development for each cluster. This is due to the fact that the countries from the same cluster mainly belong to the same quartile by the level of innovation activity, thus, the introduction of dummy variables makes no sense (*Tabl. 4*).

Table 4

Resource Factors Influencing GDP-Econometric Modelling for 1-st Cluster Countries

Indicators	OLS	FE	RE
total_mobil	**0.0305*** **	-0.0282	**0.0340*** **
	(0.00691)	(0.0453)	**(0.00937)**
RD_persons	**0.139*** **	**0.132* **	**0.138*** **
	(0.0297)	**(0.0708)**	**(0.0388)**
gov_educ	**0.862*** **	**0.707*** **	**0.816*** **
	(0.0276)	**(0.0451)**	**(0.0323)**
enrol_short	**0.00581** **	0.00469	**0.00608* **
	(0.00269)	(0.00959)	**(0.00366)**
educ_gov_exp	**0.00646* **	0.00652	**0.00787* **
	(0.00381)	(0.00866)	**(0.00477)**
enrol_PhD	**-0.0371*** **	-0.0336	**-0.0373*** **
	(0.0108)	(0.0285)	**(0.0144)**
gov_educ_GDP	**-0.170*** **	**-0.126*** **	**-0.162*** **
	(0.00735)	**(0.0183)**	**(0.00948)**
enrol_tert	**-0.0405** **	-0.0288	**-0.0466** **
	(0.0166)	(0.0243)	**(0.0188)**
Constant	4.083***	5.401***	4.428***
	(0.326)	(0.596)	(0.386)
Observations	198	198	198
R-squared	0.923	0.659	
Wald chi2:			1251,52***
Numberofcountry		18	18

Note. Calculated by the authors.

Econometric models equation (OLS-model, FE-model, RE-model):

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$$GDP_{it} = \underset{(0,326\,***)}{4,083} + \underset{(0,007***)}{0,031}\,total\_mobil_{it} + \underset{(0,030***)}{0,139}\,RD\_persons_{it} + \underset{(0,028***)}{0,862}\,gov\_educ_{it} + \underset{(0,003**)}{0,006}\,enrol\_short_{it} + \underset{(0,004*)}{0,006}\,educ\_gov\_exp_{it} - \underset{(0,011***)}{0,037}\,enrol\_PhD_{it} - \underset{(0,007***)}{0,170}\,gov\_educ\_GDP_{it},$$

$$GDP_{it} = \underset{(0,596\,***)}{5,401} - \underset{(0,045)}{0,028}\,total\_mobil_{it} + \underset{(0,071*)}{0,132}\,RD\_persons_{it} + \underset{(0,045***)}{0,707}\,gov\_educ_{it} + \underset{(0,010)}{0,005}\,enrol\_short_{it} + \underset{(0,009)}{0,007}\,educ\_gov\_exp_{it} - \underset{(0,029)}{0,034}\,enrol\_PhD_{it} - \underset{(0,018***)}{0,126}\,gov\_educ\_GDP_{it},$$

$$GDP_{it} = \underset{(0,386\,***)}{4,428} + \underset{(0,009***)}{0,0341}\,total\_mobil_{it} + \underset{(0,039***)}{0,138}\,RD\_persons_{it} + \underset{(0,032***)}{0,816}\,gov\_educ_{it} + \underset{(0,004*)}{0,006}\,enrol\_short_{it} + \underset{(0,005*)}{0,008}\,educ\_gov\_exp_{it} - \underset{(0,014***)}{0,037}\,enrol\_PhD_{it} - \underset{(0,010***)}{0,162}\,gov\_educ\_GDP_{it},$$

For countries that have formed the first cluster, government expenditures on education has the most significant impact on GDP growth. At the same time, the share of education expenditures in the overall GDP structure should be reduced. A significant positive impact of the number of R&D employees on GDP growth was identified. The quantity of students enrolled in universities and postgraduate studies have no positive effect on the GDP. Exception is that the only slight positive effect on GDP dynamics is the increase in the quantity of students enrolled in short-term courses.Increasing student mobility has a positive effect on GDP for cluster 1 countries, if we consider the overall trend over 11 years of study (OLS model).

The values of the determination coefficients (R^2 = 0.923 for the OLS model and R^2_{within} = 0.659 for the FE model) and the statistically significant Wald test for the RE model suggest that all three models are of satisfactory quality (*Tabl. 5*).

Table 5

Resource Factors Influencing GDP- Econometric Modelling for 2-nd Cluster Countries

Indicators	OLS	FE	RE
total_mobil	**-0.0828****	**-0.216*****	**-0.115****
	(0.0328)	**(0.0671)**	**(0.0555)**
gov_tertiary	**0.208*****	**-0.136***	-0.0294
	(0.0435)	**(0.0685)**	(0.0646)
gov_educ	**0.449*****	**0.959*****	**0.781*****
	(0.0526)	**(0.0897)**	**(0.0789)**
Enrol_PhD	**-0.0723****	-0.0176	0.00446
	(0.0325)	(0.0354)	(0.0345)
Constant	6.890***	5.750***	5.542***
	(0.473)	(0.606)	(0.588)
Observations	88	88	88
R-squared	0.771	0.700	
Wald chi2:			165,1***
Number of country		8	8

Note. Calculated by the authors.

Test results to determine the best specification of the model testify to the model with fixed effects:

Wald test (OLS/FE)	*Hausman test* (FE/RE)	*Breusch-Pagantest* (OLS/RE)
F = 2,94***	χ^2 = 23,12***	χ^2 = 3,51**

Econometric models equation (OLS-model, FE-model, RE-model):

$$GDP_{it} = \underset{(0,473\,***)}{6,890} - \underset{(0,033**)}{0,083}\,total\_mobil_{it} + \underset{(0,043***)}{0,208}\,gov\_tertiary_{it} + \underset{(0,053***)}{0,449}\,gov\_educ_{it} - \underset{(0,033**)}{0,072}\,enrol\_PhD_{it},$$

$$GDP_{it} = \underset{(0,606\,***)}{5,750} - \underset{(0,067***)}{0,216}\,total\_mobil_{it} - \underset{(0,069*)}{0,136}\,gov\_tertiary_{it} + \underset{(0,090***)}{0,959}\,gov\_educ_{it} - \underset{(0,035)}{0,018}\,enrol\_PhD_{it},$$

$$GDP_{it} = \underset{(0,588\,***)}{5,542} - \underset{(0,056**)}{0,115}\,total\_mobil_{it} - \underset{(0,065)}{0,029}\,gov\_tertiary_{it} + \underset{(0,079***)}{0,781}\,gov\_educ_{it} - \underset{(0,035)}{0,004}\,enrol\_PhD_{it},$$

The highest stimulating effect on GDP growth is provided by government expenditures on education: a 1% increase in it leads to almost 1% GDP growth. Instead, the increase in government expenditures on education, given the panel data structure (fixed effects model), has no positive effect on GDP. The simultaneous inclusion of *gov_tertiary* and *gov_educ*into the model is possible, since no close correlation is found between the indicators for 2-nd cluster countries.

The increase in the quantity of students leaving for study abroad has a negative impact on the level of economic growth.The reduction in the quantity of students enrolled in doctorate has a small positive effect on GDP.

According to the determination coefficients (R^2 = 0.771 for OLS model and R^2_{within} = 0.700 for FE model) and Wald criterion for RE model, we can conclude on the quality and adequacy of the models built (*Tabl. 6*).

Table 6

Resource Factors Influencing GDP-Econometric Modelling for 3-rd Cluster Countries

Indicators	OLS	FE	RE
total_mobil	**0.0290****	-0.0866	0.0175
	(0.0119)	(0.0602)	(0.0182)
gov_educ_GDP	**-0.0964*****	**-0.0923****	**-0.0886*****
	(0.0298)	**(0.0454)**	**(0.0337)**
gov_tertiary	**0.400*****	**0.413*****	**0.442*****
	(0.124)	**(0.132)**	**(0.123)**
gov_educ	**0.459*****	**0.417*****	**0.396*****
	(0.135)	**(0.134)**	**(0.132)**
Enrol_PhD	**0.0343***	**0.162*****	**0.0616*****
	(0.0179)	**(0.0461)**	**(0.0234)**
educ_gov_exp	**0.0108****	0.0146	**0.0146****
	(0.00478)	(0.0116)	**(0.00658)**
gov_tertiary_GDP	**-0.476*****	**-0.486*****	**-0.522*****
	(0.110)	**(0.158)**	**(0.116)**
Constant	4.911***	5.022***	4.975***
	(0.257)	(0.450)	(0.273)
Observations	143	143	143
R-squared	0.950	0.807	
Wald chi2:			1307,80***
Number of country		13	13

Note. Calculated by the authors.

Model with fixed effects is preferred:

Wald test (OLS/FE)	*Hausman test* (FE/RE)	*Breusch-Pagantest* (OLS/RE)
F = 17,95***	χ^2 = 22,44***	χ^2 = 54,26***

Econometric models equation (OLS-model, FE-model, RE-model):

$$GDP_{it} = \underset{(0,257\,***)}{4,911} + \underset{(0,012\,**)}{0,029}\,\text{total\_mobil}_{it} - \underset{(0,030\,***)}{0,096}\,gov\_educ\_GDP_{it} + \underset{(0,124\,***)}{0,400}\,gov\_tertiary_{it} + \underset{(0,135\,***)}{0,459}\,gov\_educ_{it} + \underset{(0,018\,*)}{0,034}\,enrol\_PhD_{it} + \underset{(0,005\,**)}{0,011}\,educ\_gov\_\exp_{it} - \underset{(0,110\,***)}{0,476}\,gov\_tertiary\_GDP_{it},$$

$$GDP_{it} = \underset{(0,450\,***)}{5,022} - \underset{(0,060)}{0,087}\,\text{total\_mobil}_{it} - \underset{(0,045\,**)}{0,092}\,gov\_educ\_GDP_{it} + \underset{(0,132\,***)}{0,413}\,gov\_tertiary_{it} + \underset{(0,134\,***)}{0,417}\,gov\_educ_{it} + \underset{(0,046\,***)}{0,162}\,enrol\_PhD_{it} + \underset{(0,012)}{0,015}\,educ\_gov\_\exp_{it} - \underset{(0,158\,***)}{0,486}\,gov\_tertiary\_GDP_{it},$$

$$GDP_{it} = \underset{(0,273\,***)}{4,975} + \underset{(0,018)}{0,018}\,\text{total\_mobil}_{it} - \underset{(0,034\,***)}{0,089}\,gov\_educ\_GDP_{it} + \underset{(0,123\,***)}{0,442}\,gov\_tertiary_{it} + \underset{(0,132\,***)}{0,396}\,gov\_educ_{it} + \underset{(0,023\,***)}{0,062}\,enrol\_PhD_{it} + \underset{(0,007\,**)}{0,015}\,educ\_gov\_\exp_{it} - \underset{(0,116\,***)}{0,522}\,gov\_tertiary\_GDP_{it},$$

As for cluster 3-rd countries, government expenditures on education and public expenditures on higher education have almost the same positive impact on GDP growth.At the same time, the share of the expenditure on education in the overall GDP structure should be reduced.This applies to both education in general and higher education in particular.

An increase in the quantity of students leaving for study abroad has a small positive effect on GDP dynamics (as for the models with individual effects, the factor *total_mobil* was statistically insignificant, thus, reasonable conclusions can be drawn only for the unified model).Increasing the number of postgraduate students has a positive effect on GDP.

The high quality of the developed models is indicated by the high values of the determination coefficients (where R^2 = 0.950 for the OLS model, and R^2_{within} = 0.8007 for the FE model), and the statistical significance of the Wald test for the RE model.

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The test results for selecting the best model are as follows:

Wald test (OLS/FE)	*Hausman test* (FE/RE)	*Breusch-Pagantest* (OLS/RE)
F = 3,12***	χ^2 = 5,88	χ^2 = 3,96**

The Wald and Breusch-Pagan tests indicated the need for a panel data structure, and the Hausman test should give preference to the random effects models. However, as already noted, the fixed effects model is more appropriate for econometric modelling of our data (*Tabl. 7*).

Table 7

Resource Factors Influencing GDP, Econometric Modelling for 4-th cluster countries

Indicators	OLS	FE	RE
total_mobil	**0.378***	0.0162	**0.378***
	(0.0612)	(0.111)	**(0.0612)**
Enrol_tert	**0.270***	**0.368***	**0.270***
	(0.0830)	**(0.0842)**	**(0.0830)**
gov_tertiary	**0.222***	**0.247***	**0.222***
	(0.0418)	**(0.0497)**	**(0.0418)**
RD_per_thous	**0.412***	**0.811***	**0.412***
	(0.0488)	**(0.0920)**	**(0.0488)**
educ_gov_exp	**0.0282***	**0.0142***	**0.0282***
	(0.00899)	**(0.00739)**	**(0.00899)**
gov_tertiary_GDP	**0.171***	0.0378	**0.171***
	(0.0639)	(0.0492)	**(0.0639)**
gov_educ_GDP	**-0.155***	**-0.261***	**-0.155***
	(0.0307)	**(0.0399)**	**(0.0307)**
Constant	2.041**	3.647***	2.041**
	(0.876)	(0.940)	(0.876)
Observations	55	55	55
R-squared	0.996	0.962	
Wald chi2:			11118,79***
Number of country		5	5

Note. Calculated by the authors

Econometric model equation (OLS model, FE model, RE model):

$$GDP_{it} = \underset{(0,876\,**)}{2,041} + \underset{(0,061***)}{0,378}\,\text{total\_mobil}_{it} + \underset{(0,083***)}{0,270}\,enrol\_tert_{it} + \underset{(0,042***)}{0,222}\,gov\_tert_{it} + \underset{(0,049***)}{0,412}\,RD\_per\_thous_{it} + \underset{(0,009***)}{0,028}\,educ\_gov\_\exp_{it} + \underset{(0,064***)}{0,171}\,gov\_tertiary\_GDP_{it} - \underset{(0,031***)}{0,155}\,gov\_educ\_GDP_{it}$$

$$GDP_{it} = \underset{(0,940\,**)}{3,647} + \underset{(0,111)}{0,016}\,\text{total\_mobil}_{it} + \underset{(0,084***)}{0,368}\,enrol\_tert_{it} + \underset{(0,050***)}{0,247}\,gov\_tert_{it} + \underset{(0,092***)}{0,811}\,RD\_per\_thous_{it} + \underset{(0,007***)}{0,014}\,educ\_gov\_\exp_{it} + \underset{(0,049)}{0,038}\,gov\_tertiary\_GDP_{it} - \underset{(0,040***)}{0,261}\,gov\_educ\_GDP_{it}$$

For 4-th cluster countries, the most significant impact on GDP growth is the increase in the quantity of R&D employees. Public expenditure on higher education has a significant positive impact on GDP growth. The negative factor with the variable *gov_educ_GDP* means that GDP growth is accompanied by a reduction in the share of education expenditures in the overall GDP structure. The quantity of students enrolled in universities also has a significant impact on GDP growth.

The high quality of the developed models is indicated by the high values of the determination coefficients (where R^2 = 0.9996 for the OLS model, and R^2_{within} = 0.962 for the FE model), and the statistical significance of the Wald test for the RE model.

Test results for the best model selection indicate in favour of the fixed effects model:

Wald test (OLS/FE)	*Hausman test* (FE/RE)	*Breusch-Pagantest* (OLS/RE)
F = 18,12***	χ^2 = 105,61***	χ^2 = 0

Zero value for the Breusch-Pagan test means that the combined model and the random effects model both have given exactly the same results for estimating the model coefficients, so it is senseless to use the random effects model (*Tabl. 8*).

Table 8

Resulting Factors Influencing GDP, Econometric Modelling for 1-st cluster countries

Indicators	OLS	FE	RE
mobile_sub	**0.327*** **	**0.0941***	**0.128****
	(0.0845)	(0.0552)	(0.0559)
trademark_res	**-0.214*****	0.0535	0.00991
	(0.0334)	(0.0452)	(0.0430)
hi-tech_exp	**0.0519*****	**-0.0651*****	**-0.0370***
	(0.0197)	(0.0230)	(0.0210)
trademark_nres	**0.0288****	**0.0837*****	**0.0780*****
	(0.0132)	(0.0234)	(0.0208)
research_exp	**0.493*****	**0.734*****	**0.681*****
	(0.0453)	(0.0433)	(0.0413)
design_nres	**0.0270*****	-0.0133	-0.0109
	(0.00851)	(0.0128)	(0.0119)
design_res	**-0.0265****	**-0.0416*****	**-0.0420*****
	(0.0120)	(0.0114)	(0.0113)
patent_nres	**0.0704*****	-0.0130	-0.0124
	(0.0129)	(0.00964)	(0.00956)
patent_res	**-0.140*****	0.0372	0.0146
	(0.0188)	(0.0225)	(0.0216)
Constant	7.172***	4.916***	5.369***
	(0.519)	(0.424)	(0.416)
Observations	198	198	198
R-squared	0.721	0.785	
Wald chi2:			579,59***
Number of country		18	18

Note: The reference: Calculated by the authors.

Econometric model equation (OLS model, FE model, RE model):

$$GDP_{it} = \underset{(0{,}519^{***})}{7{,}172} + \underset{(0{,}085^{***})}{0{,}327} mobile\_sub_{it} - \underset{(0{,}033^{***})}{0{,}214} trademark\_res_{it} + \underset{(0{,}020^{***})}{0{,}052} hi-tech\_\exp_{it} + \underset{(0{,}013^{***})}{0{,}029} trademark\_nres_{it} + \underset{(0{,}045^{***})}{0{,}493} research\_\exp_{it} + \underset{(0{,}009^{***})}{0{,}027} design\_nres_{it} - \underset{(0{,}012^{**})}{0{,}027} design\_res_{it} + \underset{(0{,}013^{***})}{0{,}071} patent\_nres_{it} - \underset{(0{,}019^{***})}{0{,}140} patent\_res_{it}$$

$$GDP_{it} = \underset{(0{,}424^{***})}{4{,}916} + \underset{(0{,}055^{*})}{0{,}094} mobile\_sub_{it} + \underset{(0{,}045)}{0{,}054} trademark\_res_{it} - \underset{(0{,}023^{***})}{0{,}065} hi-tech\_\exp_{it} + \underset{(0{,}023^{***})}{0{,}084} trademark\_nres_{it} + \underset{(0{,}043^{***})}{0{,}734} research\_\exp_{it} - \underset{(0{,}013)}{0{,}013} design\_nres_{it} - \underset{(0{,}011^{***})}{0{,}042} design\_res_{it} - \underset{(0{,}010)}{0{,}013} patent\_nres_{it} + \underset{(0{,}023)}{0{,}037} patent\_res_{it}$$

$$GDP_{it} = \underset{(0{,}416^{***})}{5{,}369} + \underset{(0{,}056^{**})}{0{,}128} mobile\_sub_{it} + \underset{(0{,}043)}{0{,}010} trademark\_res_{it} - \underset{(0{,}021^{*})}{0{,}037} hi-tech\_\exp_{it} + \underset{(0{,}021^{***})}{0{,}078} trademark\_nres_{it} + \underset{(0{,}041^{***})}{0{,}681} research\_\exp_{it} - \underset{(0{,}012)}{0{,}011} design\_nres_{it} - \underset{(0{,}011^{***})}{0{,}042} design\_res_{it} - \underset{(0{,}010)}{0{,}012} patent\_nres_{it} + \underset{(0{,}022)}{0{,}015} patent\_res_{it}$$

For 1-st cluster countries, R&D expenditure has a key positive effect on economic development. It has been found that the growth of high-tech exports under the integrated model has a positive effect on economic development level, and, in the same time, it has a negative effect on the models that take into account individual effects. Therefore, as a rule, higher high-tech exports' value corresponds to higher GDP value, but if we consider each country as a separate entity, the growth of high-tech exports has a negative impact on the country's economic development level. Improving the information infrastructure has a little positive impact on the economic development level. Increase in non-resident intellectual property assets has a positive impact on GDP.

The high quality of the developed models is indicated by the high values of the determination coefficients (where R^2 = 0.721 for the OLS model, and R^2_{within} = 0.785 for the FE model), and the statistical significance of the Wald test for the RE model (*Tabl. 9*).

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Table 9

Resulting Factors Influencing GDP, Econometric Modelling for 2-nd cluster countries

Indicators	OLS	FE	RE
mobile_sub	**0.855*** **	**0.945*** **	**0.855*** **
	(0.178)	(0.184)	(0.178)
intern_users	**0.00258** **	**0.00257** **	**0.00258** **
	(0.00127)	(0.00128)	(0.00127)
hi-tech_exp	**-0.152*** **	**-0.147*** **	**-0.152*** **
	(0.0300)	(0.0303)	(0.0300)
ICT_exp	**-0.0285*** **	**-0.0316*** **	**-0.0285*** **
	(0.0104)	(0.0108)	(0.0104)
ICT_imp	**0.0433*** **	**0.0467*** **	**0.0433*** **
	(0.0116)	(0.0121)	(0.0116)
design_nres	**0.0902*** **	**0.0937*** **	**0.0902*** **
	(0.0208)	(0.0214)	(0.0208)
patent_res	**-0.101* **	**-0.125** **	**-0.101* **
	(0.0537)	(0.0567)	(0.0537)
research_exp	**0.340*** **	**0.350*** **	**0.340*** **
	(0.0474)	(0.0493)	(0.0474)
Constant	5.197***	4.728***	5.197***
	(0.834)	(0.866)	(0.834)
Observations	88	88	88
R-squared	0.724	0.738	
Wald chi2:			204,62***
Number of country		8	8

The reference: Calculated by the authors.

Test results for the best model selection indicate in favour of the fixed effects model:

Wald test (OLS/FE)	*Hausman test* (FE/RE)	*Breusch-Pagantest* (OLS/RE)
F = 64,23***	χ^2 = 363,03***	χ^2 = 424,07***

Econometric model equation (OLS model, FE model, RE model):

$$GDP_{it} = \underset{(0,834\,***)}{5,197} + 0,855\underset{(0,178***)}{mobile\_sub_{it}} + 0,003\underset{(0,001**)}{intern\_users_{it}} - 0,152\underset{(0,030***)}{hi-tech\_\exp_{it}} - 0,029\underset{(0,010***)}{ITC\_\exp_{it}} + 0,043\underset{(0,012***)}{ITC\_imp_{it}} + 0,090\underset{(0,021***)}{design\_nres_{it}} - 0,101\underset{(0,054*)}{patent\_res_{it}} + 0,340\underset{(0,048***)}{research\_\exp_{it}}$$

$$GDP_{it} = \underset{(0,866\,***)}{4,728} + 0,945\underset{(0,184***)}{mobile\_sub_{it}} + 0,003\underset{(0,001**)}{intern\_users_{it}} - 0,147\underset{(0,030***)}{hi-tech\_\exp_{it}} - 0,032\underset{(0,011***)}{ITC\_\exp_{it}} + 0,047\underset{(0,012***)}{ITC\_imp_{it}} + 0,094\underset{(0,021***)}{design\_nres_{it}} - 0,125\underset{(0,057***)}{patent\_res_{it}} + 0,350\underset{(0,049***)}{research\_\exp_{it}}$$

The amount of expenditures invested in research and development have a positive impact on GDP. Improving the information infrastructure also has a little positive impact on the economic development level. The rise in high-tech exports and ICT exports is undesirable and leads to a slowdown in economic development, while an increase in the ICT goods' share imports in the overall import structure has a positive effect on GDP growth. The increase in quantity of non-residents providing industrial design services has a positive impact on the economic development level.

The high quality of the developed models is indicated by high values of the determination coefficients (where R^2 = 0,724 for the OLS model, and R^2_{within} =0,738 for the FE model), and the statistical significance of the Wald test for the RE model (*Tabl. 10*).

Table 10

Resulting Factors Influencing GDP, Econometric Modelling for 3-rd cluster countries

Indicators	OLS	FE	RE
research_exp	**0.370*** **	**0.507*** **	**0.504*** **
	(0.0356)	(0.0389)	(0.0395)
intern_users	**0.00928*** **	**0.00345*** **	**0.00376*** **
	(0.00144)	(0.00103)	(0.00105)
trademark_nres	**0.109*** **	**0.297*** **	**0.213*** **
	(0.0332)	(0.0452)	(0.0398)
hi-tech_exp	**-0.0844*** **	**0.0626* **	0.00624
	(0.0237)	(0.0368)	(0.0324)
trademark_res	**0.212*** **	-0.0670	0.00189
	(0.0412)	(0.0744)	(0.0702)
ICT_imp	**0.0332*** **	-0.00905	-0.00335
	(0.00547)	(0.00561)	(0.00575)
design_nres	**-0.0675*** **	0.00249	0.00396
	(0.0147)	(0.0108)	(0.0111)
Constant	5.524***	5.359***	5.625***
	(0.257)	(0.442)	(0.423)
Observations	143	143	143
R-squared	0.831	0.852	
Wald chi2:			633,35***
Number of country		13	13

The reference: Calculated by the authors.

The tests' results for choosing the best model refute the hypothesis of a panel structure's presence in the data:

Wald test (OLS/FE)	*Hausman test* (FE/RE)	*Breusch-Pagantest* (OLS/RE)
F = 0,85	$\chi^2 = 4,71$	$\chi^2 = 0$

When modelling the resulting indicators influencing GDP, the same coefficients for the OLS and RE models and the very similar coefficients in the FE model also indicate the absence of unobserved individual characteristics in the 2-nd cluster countries. Thus, a unified cross-regression model is modelling the real data most adequately.

Econometric model equation (OLS model, FE model, RE model):

$$GDP_{it} = \underset{(0,257\,***)}{5,524} + \underset{(0,036***)}{0,370} research\_\exp_{it} + \underset{(0,001***)}{0,009} intern\_users_{it} + \underset{(0,033***)}{0,109} trademark\_nres_{it} - \underset{(0,024***)}{0,084} hi-tech\_\exp_{it} + \underset{(0,041***)}{0,212} trademark\_res_{it} + \underset{(0,005***)}{0,033} ITC\_imp_{it} - \underset{(0,015***)}{0,068} design\_nres_{it}$$

$$GDP_{it} = \underset{(0,442\,***)}{5,359} + \underset{(0,039***)}{0,507} research\_\exp_{it} + \underset{(0,001***)}{0,003} intern\_users_{it} + \underset{(0,045***)}{0,297} trademark\_nres_{it} + \underset{(0,037*)}{0,063} hi-tech\_\exp_{it} - \underset{(0,074)}{0,067} trademark\_res_{it} - \underset{(0,006)}{0,009} ITC\_imp_{it} + \underset{(0,011)}{0,002} design\_nres_{it}$$

$$GDP_{it} = \underset{(0,423\,***)}{5,625} + \underset{(0,040***)}{0,504} research\_\exp_{it} + \underset{(0,001***)}{0,004} intern\_users_{it} + \underset{(0,040***)}{0,213} trademark\_nres_{it} + \underset{(0,032)}{0,062} hi-tech\_\exp_{it} - \underset{(0,070)}{0,002} trademark\_res_{it} - \underset{(0,006)}{0,003} ITC\_imp_{it} + \underset{(0,011)}{0,004} design\_nres_{it}$$

For 3-rd cluster countries, the most significant impact on GDP growth is provided by the increase in R&D expenditure. Registration of new trademarks for both residents and non-residents contributes to economic growth. There is a small but statistically significant correlation between the quantity of Internet users and GDP growth. Growth in high-tech exports in the unified model is found to have a negative impact on economic development, but, in the same time, it has a positive impact on GDP by the models that take into account the individual features of each country. That is, if we consider each country as a separate entity, the growth of high-tech export volumes has a positive impact on the country's economic development level.

The high quality of the developed models is indicated by the high values of the determination coefficients (where R^2 = 0.831 for the OLS model, and R^2_{within} = 0.852 for the FE model), and the statistical significance of the Wald test for the RE model (*Tabl. 11*).

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Table 11

Resulting Factors Influencing GDP, Econometric Modelling for 4-th cluster countries

Indicators	OLS	FE	RE
research_exp	**0.441***** (0.0426)	**0.499***** (0.0607)	**0.441***** (0.0426)
trademark_nres	**0.0784***** (0.0291)	0.0625 (0.0395)	**0.0784***** (0.0291)
intern_users	**0.00763***** (0.00190)	**0.00686***** (0.00246)	**0.00763***** (0.00190)
hi-tech_exp	**0.00002***** (0.000002)	**0.000002** (0.000006)	**0.00002***** (0.000002)
mobile_sub	**0.126***** (0.0277)	**0.119***** (0.0327)	**0.126***** (0.0277)
ICT_imp	**0.00551***** (0.00187)	0.00401 (0.00315)	0.00551*** (0.00187)
Constant	5.292*** (0.122)	5.330*** (0.324)	5.292*** (0.122)
Observations	55	55	55
R-squared	0.998	0.963	
Wald chi2:			1204,22***
Numberofcountry		5	5

The reference: Calculated by the authors.

Test results for the best model selection indicate in favour of the fixed effects model:

Wald test (OLS/FE)	*Hausman test* (FE/RE)	*Breusch-Pagantest* (OLS/RE)
F = 48.55***	χ^2 = 117.33***	χ^2 = 180.26***

Econometric model equation (OLS model, FE model, RE model):

$$GDP_{it} = \underset{(0,122***)}{5,292} + \underset{(0,043***)}{0,441} research\_\exp_{it} + \underset{(0,030***)}{0,078} trademark\_nres_{it} + \underset{(0,001***)}{0,008} intern\_users_{it} + \underset{(0,000002***)}{0,00002} hi-tech\_\exp_{it} + \underset{(0,028***)}{0,126} mobile\_sub_{it} + \underset{(0,002***)}{0,006} ITC\_imp_{it} +$$

$$GDP_{it} = \underset{(0,324***)}{5,330} + \underset{(0,061***)}{0,449} research\_\exp_{it} + \underset{(0,040)}{0,063} trademark\_nres_{it} + \underset{(0,002***)}{0,007} intern\_users_{it} + \underset{(0,000006)}{0,000002} hi-tech\_\exp_{it} + \underset{(0,033***)}{0,119} mobile\_sub_{it} + \underset{(0,003***)}{0,004} ITC\_imp_{it} +$$

The research-and-development expenditure has a leading positive impact on GDP growth in 4-th cluster countries. The information infrastructure development has a positive impact on GDP. According to the coefficients, such factors as the increase in high-tech exports, the share of ICT goods' imports, and the quantity of non-residents providing industrial design services have a small positive effect on GDP.

The high quality of the developed models is indicated by the high values of the determination coefficients (where R^2 = 0.996 for the OLS model, and R^2_{within} = 0.962 for the FE model), and the statistical significance of the Wald test for the RE model.

The test results for the best model selection indicate in favour of the fixed effects model:

Wald test (OLS/FE)	*Hausman test* (FE/RE)	*Breusch-Pagantest* (OLS/RE)
F = 3.41**	χ^2 = 47.46*	χ^2 = 0

Conclusions. Basing on the system of indicators for use and reproduction of intellectual capital, the countries were stratified by the level of intellectualization success. A clear topography for innovative development of forty-four most developed countries has been formed. The whole set of countries differentiated according to the key intellectualization factors into four clusters with common development features in both static and dynamic plane.

The key factors influencing GDP of the countries for each group were identified, and the intellectual models for perspective development of the countries positioned in the clusters were characterized. This makes it possible to make realistic prognostic scenarios for their development, taking into account both changes in individual model components and the efficiency of different economic measures and instruments. Correlation-and-regression analysis has revealed 4 key clusters for the countries with common development features.

As a result of the simulations, the following regularities were revealed for each cluster. For first cluster countries the most significant impact on GDP growth is exerted by the government's expenditures on education and the research staff growth. For the second cluster countries growth in expenditures on education by 1% leads to a 1% increase in GDP. The third cluster countries are experiencing a significant positive impact from rising expenditures on education in general and on higher education in particular. The fourth cluster countries are experiencing a significant positive impact from the increase in research staff and the increase in public expenditures on higher education.

The most influential performance indicators of intellectual activity were also identified. The research-and-development expenditure has the biggest positive impact on GDP growth for the first cluster countries. For second cluster countries these indicators are complemented by the information infrastructure available. For the third cluster countries the most significant impact is the increase in the R&D expenditure and raising capital from abroad, which gives a rather rapid economic effect. For fourth cluster countries, in addition to the classical factors of influence, the share of high-tech goods exports has a positive effect.

Overall, a close linear relationship between GDP per capita and R&D expenditures, the quantity of scientific and technical publications, the quantity of researchers in the R&D industry and the share of the population using the Internet was confirmed. A moderate correlation exists between the GDP value and industrial design of non-resident applications.

The results of modelling the impact of resource level factors indicate that public expenditure on education has the most positive impact on the country's economic development level: if this indicator increases by 1%, it leads to an increase in GDP by 0.8% and increase in the quantity of employees engaged in the R&D implementation by 1%, which allows for an increase in GDP by 0.15%.

The simulation results showed that R&D expenditure has a leading stimulating effect on the GDP growth. Increasing R&D expenditure by 1% enables GDP to increase by 0.55% approximately. The increase in the innovative enterprises' share in the country is also a significant factor in GDP growth.

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