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IDENTIFYING THE RELATIONSHIP BETWEEN HIGHER EDUCATION RESOURCES AND ENTERPRISE INNOVATION ACTIVITY

The article examines the relationship between higher education resources and enterprise innovation activity across Kazakhstan's regions. The study aims to assess the direction and robustness of associations between higher education indicators and the share of innovation-active enterprises. Official data from the Bureau of National Statistics for 2018–2025 were analysed. A territorially comparable panel covering 17 regions was constructed, accounting for administrative changes. Descriptive statistics and regression models with region and year fixed effects, one-year lags of explanatory variables, and clustered standard errors were applied. Statistical significance was assessed using a wild cluster bootstrap.

Differences in educational, scientific, and economic indicators were identified. The baseline model yielded a positive association between student numbers relative to population and enterprise innovation activity, significant at the 10% level. After R&D personnel numbers were included, statistical support for this association was no longer established. No statistically significant associations were found for graduate numbers or teaching staff numbers. Statistical conclusions were shown to depend on the explanatory variables included. Opportunities for using the findings to assess university-enterprise interaction were identified. The empirical novelty lies in comparing three higher education indicators within a regional panel while accounting for economic conditions and scientific personnel. The estimates represent conditional statistical associations.

Keywords: human capital, knowledge transfer, interregional mobility, spatial heterogeneity, technological cooperation, skilled labour market, absorptive capacity.

Кілт сөздер: адами капитал, білім трансфері, өңіраралық ұтқырлық, кеңістіктік әркелкілік, технологиялық ынтымақтастық, білікті еңбек нарығы, білімді игеру қабілеті.

Ключевые слова: человеческий капитал, трансфер знаний, межрегиональная мобильность, пространственная неоднородность, технологическое сотрудничество, рынок квалифицированного труда, абсорбционная способность.

Introduction. Higher education provides the human capital and research foundation of an innovation-driven economy. Universities train specialists, generate knowledge, and undertake joint projects with enterprises. However, the regional outcomes of these processes depend on the conditions for interaction between science and business [1]. Expanding educational resources therefore requires an assessment of their relationship with enterprise innovation activity.

The relevance of this study to Kazakhstan stems from differences in the location of universities, economic structure, and the availability of research personnel. Student numbers reflect the location of study, while graduates may apply their qualifications in other regions [2-4]. It remains unclear whether associations between educational indicators and innovation activity [5] persist after accounting for economic conditions and scientific resources [6-7].

The study aims to establish the direction and robustness of statistical associations between student enrolment, graduate output, and teaching staff and the innovation activity of enterprises across Kazakhstan's regions. The objectives are to:

- construct a territorially comparable panel of educational, scientific, and economic indicators for Kazakhstan's regions;
- test three hypotheses concerning the associations of student numbers, graduate output, and teaching staff numbers with enterprise innovation activity;
- assess the robustness of the identified associations after additionally accounting for regional research personnel.

The study used official data from the Bureau of National Statistics for 2018-2025 [8]. Territorial comparability was ensured by aggregating indicators for newly established regions with those of their original regions. Educational and scientific indicators were calculated relative to population size. Descriptive statistics and panel regressions with region and year fixed effects were applied. Explanatory variables were included with a one-year lag. Nominal gross regional product per capita and the share of manufacturing were controlled for. Standard errors were clustered by region. Statistical significance was assessed using a wild cluster bootstrap. The results are interpreted as conditional statistical associations.

Literature review. The relationship between higher education and innovation is examined through workforce training, knowledge creation, and interaction with enterprises. Bonaccorsi et al. identified complementarities between universities' teaching and research activities, with graduate training making a notable contribution to enterprise performance [1]. Joshkun et al. demonstrated the importance of digital infrastructure for developing literacy, although their study of schoolchildren does not examine regional innovation outcomes [2]. Akimov et al. synthesised 48 studies on open innovation competencies, emphasising the need to develop skills alongside technological provision [3].

Faggian and McCann link regional innovation to graduate mobility. The location of study therefore does not necessarily coincide with the location where qualifications are applied [4]. Kurmanov et al. examine regional heterogeneity in Kazakhstan's conditions [5]. Perkmann et al. identify organisational conditions for collaboration between researchers and business [6], while Medina-Bueno et al. examine institutional barriers to university engagement in resource-based regions [7].

This synthesis indicates that the scale of educational resources does not guarantee innovation outcomes. Their relationship with enterprise innovation activity in Kazakhstan remains insufficiently understood. Accordingly, the study tests hypotheses concerning positive associations between student, graduate, and teaching staff numbers relative to population size and enterprise innovation activity.

Main section. A panel comprising 136 observations across 17 comparable territories of Kazakhstan for 2018–2025 was constructed to assess the relationship between higher education and enterprise innovation activity [8]. Table 1 summarises the distribution of the educational, scientific, and economic indicators used in the regression analysis.

Table – 1

Descriptive statistics for the study variables*

Variable	N	Mean	Standard deviation	Min.	Max.
Enterprise innovation activity, %	136	10.13	3.61	3.44	18.39
Students per 10,000 population	136	286.80	233.41	47.73	1,049.24
Graduates per 10,000 population	136	75.47	63.21	8.62	304.19
Teaching staff per 10,000 population	136	17.18	15.00	0.45	69.45
R&D personnel per 10,000 population	134	10.47	11.69	0.91	51.32
Nominal GRP per capita, million tenge	136	5.41	4.11	0.84	23.33
Manufacturing share of GRP, %	136	14.43	9.06	2.81	35.83

*calculated by the authors using data from [8].

Table 1 reveals substantial differences in enterprise innovation activity across regional observations. The indicator ranges from 3.44 to 18.39%, with a mean of 10.13%. For example, Mangystau Region recorded the minimum value in 2019. Pavlodar Region reached the maximum in 2024. The difference between the regions was 14.95 percentage points.

The mean number of students in Kazakhstan was 286.80 per 10,000 population, with a standard deviation of 233.41. Turkestan Region recorded 47.73 students per 10,000 population in 2022, compared with 1,049.24 in the city of Shymkent in 2019. These values describe the distribution of students by location of study. The data do not directly measure access to higher education for regional residents. Similar heterogeneity was observed in graduate output. The mean reached 75.47 graduates per 10,000 population, with a range of 8.62–304.19.

Human resources in higher education and science are also unevenly distributed. The mean numbers of teaching staff and R&D personnel were 17.18 and 10.47 per 10,000 population, respectively. The standard deviations reached 15.00 and 11.69, respectively, indicating substantial dispersion across observations. Because two confidential values for R&D personnel were unavailable, 134 observations were used instead of 136.

Regional economic conditions differ to a similar extent. Nominal GRP per capita ranges from 0.84 to 23.33 million tenge. The manufacturing share of GRP ranged from 2.81 to 35.83%. Both indicators are therefore included in the regressions. Persistent characteristics of Kazakhstan's territories and common annual changes are controlled for using region and year fixed effects. The three baseline models separately test the associations of innovation activity with student numbers, graduate numbers, and teaching staff numbers. Explanatory variables are included with a one-year lag. Table 2 presents the estimates obtained from a common sample of 118 observations for 2019–2025.

Table – 2

Baseline models of the relationship between higher education and enterprise innovation activity*

Variable / characteristic	Model 1. Students, H1	Model 2. Graduates, H2	Model 3. Teaching staff, H3
Students per 10,000 population, t–1	0.0111* (0.0055)	-	-
Graduates per 10,000 population, t–1	-	0.0116 (0.0303)	-
Teaching staff per 10,000 population, t–1	-	-	0.1085 (0.1741)
Log of nominal GRP per capita, t–1	-4.6209** (2.3979)	-4.2408** (2.4906)	-4.6683** (2.8186)
Manufacturing share of GRP, t–1	-0.0245 (0.2054)	0.0049 (0.2044)	-0.0065 (0.2080)
<i>p</i> for the higher education indicator: cluster-based test	0.061	0.707	0.542
<i>p</i> for the higher education indicator: wild bootstrap	0.073	0.687	0.507
R ² within	0.073	0.039	0.043
Number of observations	118	118	118
Number of territories	17	17	17
Period covered by the dependent variable	2019-2025	2019-2025	2019-2025
Region and year fixed effects	Yes	Yes	Yes
Hypothesis test result	Weak support for H1 at 10%	H2 not supported	H3 not supported

*calculated by the authors according to the data of the source [8]. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

Table 2 shows a positive association between student numbers relative to population size and enterprise innovation activity in the baseline model. The coefficient was 0.0111, with a clustered standard error of 0.0055. Holding other factors constant, an increase of 100 students per 10,000 population in the preceding year is associated with a 1.11 percentage point increase in innovation activity. However, statistical support for H1 is limited to the 10% level. The cluster-based test yields $p = 0.061$, while the cluster bootstrap yields $p = 0.073$.

Positive coefficients of 0.0116 and 0.1085 were obtained for graduate numbers and teaching staff numbers, respectively, but neither association was statistically significant. The bootstrap test yields $p = 0.687$ for graduates and $p = 0.507$ for teaching staff. Accordingly, H2 and H3 were not supported. These results do not establish the absence of an association. A one-year lag and regional indicators drawn from statistical observations may not fully capture graduate employment and university–enterprise interaction.

A negative association with innovation activity was observed for the log of nominal GRP per capita. The coefficients range from -4.2408 to -4.6683 and are significant at the 5% level according to the bootstrap test. They cannot be interpreted as a negative effect of economic development because GRP is measured at current prices and the estimates represent conditional statistical associations. The coefficients

for the manufacturing share are close to zero, ranging from -0.0245 to 0.0049 , and are statistically insignificant in all three models.

After removing region and year effects, the models explain between 3.9 and 7.3% of the remaining variation in innovation activity. The highest R^2 within, 0.073, was obtained in the model with students. This value alone does not establish the superiority of this indicator over graduate output or teaching staff numbers. To assess robustness, lagged R&D personnel numbers per 10,000 population were additionally included in each specification. The extended models were estimated using the same sample of 118 observations across 17 territories. Table 3 presents the results.

Table – 3

Robustness assessment accounting for regional scientific resources*

Variable / characteristic	Model 4. Students, H1	Model 5. Graduates, H2	Model 6. Teaching staff, H3
Students per 10,000 population, t-1	0.0107 (0.0052)	-	-
Graduates per 10,000 population, t-1	-	0.0024 (0.0298)	-
Teaching staff per 10,000 population, t-1	-	-	0.1016 (0.1802)
Log of nominal GRP per capita, t-1	-4.6659** (2.2223)	-4.2092** (2.2172)	-4.7014** (2.5850)
Manufacturing share of GRP, t-1	-0.0314 (0.2050)	-0.0052 (0.2017)	-0.0142 (0.2065)
R&D personnel per 10,000 population, t-1	0.2252 (0.2018)	0.2337 (0.2215)	0.2340 (0.2216)
p for the higher education indicator: cluster-based test	0.057	0.936	0.581
p for the higher education indicator: wild bootstrap	0.128	0.932	0.576
R^2 within	0.101	0.067	0.073
Number of observations	118	118	118
Number of territories	17	17	17
Period covered by the dependent variable	2019–2025	2019–2025	2019–2025
Region and year fixed effects	Yes	Yes	Yes
Hypothesis test result	Support for H1 is not robust	H2 not supported	H3 not supported

*calculated by the authors according to the data of the source [8]. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$.

Table 3 shows that, after regional scientific resources were included, the coefficient for student numbers remained positive and declined from 0.0111 to 0.0107. An increase of 100 students per 10,000 population in the preceding year is associated with an increase in innovation activity of approximately 1.07 percentage points. However, the association was no longer significant according to the cluster bootstrap test. P increased from 0.073 to 0.128, indicating that support for H1 was not robust.

Coefficients of 0.0024 and 0.1016 were obtained for graduate numbers and teaching staff numbers, respectively. Neither was statistically significant in the corresponding extended specification. The graduate coefficient declined by approximately 79% relative to the baseline model, while the estimate for teaching staff declined by 6%. The results in Table 3 do not support H2 or H3 after accounting for R&D personnel numbers.

The positive coefficients for research personnel ranged from 0.2252 to 0.2340, but their statistical significance was not established. Bootstrap p -values range from 0.364 to 0.421. Including the R&D indicator increased R^2 within from 0.073 to 0.101 in the student model, from 0.039 to 0.067 in the graduate model, and from 0.043 to 0.073 in the teaching staff model. The extended models explain a slightly larger proportion of the variation in innovation activity. However, none of the educational indicators exhibits a robust statistically significant association at the 5% level. These findings provide the basis for the

concluding assessment of the relationship between higher education resources and enterprise innovation activity in Kazakhstan.

Conclusion. This study assessed the relationship between higher education resources and enterprise innovation activity using a panel of 136 observations across 17 territories of Kazakhstan for 2018-2025. The study's objective was achieved by testing three hypotheses in six regression models with region and year fixed effects, one-year lags of explanatory variables, and a common sample of 118 observations.

A positive association between student numbers relative to population size and innovation activity was identified in the baseline model. An increase of 100 students per 10,000 population is associated with a 1.11 percentage point increase in the share of innovation-active enterprises. After R&D personnel were included, the estimate was 1.07 percentage points. However, the bootstrap test did not confirm its statistical significance. The hypotheses concerning positive associations of graduate output and teaching staff numbers with innovation activity also received no statistical support. Thus, none of the three educational indicators demonstrated robust significance at the 5% level.

The empirical novelty lies in testing three educational indicators while accounting for economic conditions and research personnel within a territorially comparable panel that incorporates the administrative changes of 2022. Comparing the baseline and extended models showed that the coefficient for student numbers remains positive, but statistical support for this association depends on the specification.

The findings can be used to assess regional programmes supporting interaction between the country's universities and enterprises. Since quantitative resources alone are insufficient to assess such interaction, student, graduate, and teaching staff indicators should be supplemented with information on joint projects, employment, and the implementation of research outputs.

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ЖОҒАРЫ БІЛІМ БЕРУ РЕСУРСТАРЫ МЕН КӘСІПОРЫНДАРДЫҢ ИННОВАЦИЯЛЫҚ БЕЛСЕНДІЛІГІ АРАСЫНДАҒЫ БАЙЛАНЫСТЫ АНЫҚТАУ

Аңдатпа

Мақалада жоғары білім беру ресурстарының Қазақстан өңірлеріндегі кәсіпорындардың инновациялық белсенділігімен байланысы қарастырылған. Зерттеудің мақсаты - білім беру көрсеткіштері мен инновациялық белсенді кәсіпорындар үлесі арасындағы байланыстардың бағыты мен орнықтылығын бағалау. Ұлттық статистика бюросының 2018-2025 жылдардағы ресми деректері талданған. Әкімшілік өзгерістер ескеріліп, 17 өңір бойынша аумақтық тұрғыдан салыстырмалы панельдік деректер жиынтығы қалыптастырылған. Сипаттамалық статистика және өңірлер мен жылдардың тұрақты әсерлері, түсіндіруші айнымалылардың бір жылдық лагтары және кластерлік стандартты қателері бар регрессиялық модельдер қолданылған. Статистикалық мәнділік жабайы кластерлік бутстрэп әдісімен тексерілген.

Білім беру, ғылыми және экономикалық көрсеткіштер арасындағы айырмашылықтар анықталған. Базалық модельде студенттердің халық санына шаққандағы саны мен инновациялық белсенділік арасында он пайыздық деңгейде статистикалық мәнді оң байланыс алынған. Ғылыми зерттеулер мен тәжірибелік-конструкторлық әзірлемелерді орындайтын қызметкерлер саны енгізілгеннен кейін бұл байланыстың статистикалық мәнділігі расталмаған. Түлектер саны мен оқытушылар саны үшін статистикалық мәнді байланыстар анықталмаған. Статистикалық қорытындылардың түсіндіруші айнымалылар құрамына тәуелділігі көрсетілген. Нәтижелерді жоғары оқу орындары мен кәсіпорындардың өзара іс-қимылын бағалауда пайдалану мүмкіндіктері айқындалған. Эмпирикалық жаңалық экономикалық жағдайлар мен ғылыми кадрларды ескере отырып, өңірлік панельде үш білім беру көрсеткішін салыстырудан тұрады. Алынған бағалаулар шартты статистикалық байланыстарды сипаттайды.

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**ВЫЯВЛЕНИЕ СВЯЗИ РЕСУРСОВ ВЫСШЕГО ОБРАЗОВАНИЯ С ИННОВАЦИОННОЙ
АКТИВНОСТЬЮ ПРЕДПРИЯТИЙ**

Аннотация

В статье рассмотрена связь ресурсов высшего образования с инновационной активностью предприятий регионов Казахстана. Цель исследования состоит в оценке направления и устойчивости связей образовательных показателей с долей инновационно активных предприятий. Проанализированы официальные данные Бюро национальной статистики за 2018–2025 гг. Сформирована территориально сопоставимая панель по 17 регионам с учётом административных изменений. Применены описательная статистика и регрессионные модели с фиксированными эффектами регионов, и лет, годовыми лагами объясняющих переменных и кластерными стандартными ошибками. Статистическая значимость проверена диким кластерным бутстрэпом.

Выявлены различия образовательных, научных и экономических показателей. В базовой модели получена положительная связь удельной численности студентов с инновационной активностью, значимая на десятипроцентном уровне. После включения численности работников НИОКР статистическая поддержка этой связи утрачена. Для выпуска специалистов и численности преподавателей значимые связи не установлены. Показана зависимость статистических выводов от состава объясняющих переменных. Определены возможности использования результатов при оценке взаимодействия вузов и предприятий. Эмпирическая новизна заключается в сопоставлении трёх образовательных показателей с учётом экономических условий и научных кадров на региональной панели. Полученные оценки характеризуют условные статистические ассоциации.

