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INTEGRATION OF KAZAKHSTAN'S REGIONS INTO R&D AND THE DEVELOPMENT OF THEIR INTELLECTUAL POTENTIAL

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Abstract. *The relevance* of the study is determined by the need to strengthen the integration of the regions of the Republic of Kazakhstan into research and development (R&D) processes as a key factor in enhancing the country's intellectual potential and training a new generation of specialists. Despite ongoing state reforms, significant territorial disparities persist in terms of scientific activity, development of digital infrastructure, and availability of qualified human resources. The concentration of scientific resources and research infrastructure in the cities of Astana and Almaty limits the participation of peripheral regions in innovation processes and reduces their competitiveness. *The purpose* of the study is to provide a theoretical and methodological justification of mechanisms for integrating Kazakhstan's regions into R&D activities and to assess the factors influencing the spatial distribution of scientific and innovative potential. *The research methods* are based on systemic, institutional, and evolutionary economic approaches and include comparative, statistical, and structural-logical analysis. The empirical basis of the study comprises data from Stat.gov.kz, the OECD, UNESCO, and the World Bank. The analysis employs indicators of R&D intensity, number of researchers, publication activity, the level of digitalization of vocational and higher education institutions, and employment in high-technology sectors of the economy. *The research results* reveal a high concentration of scientific potential in two major metropolitan areas, pronounced

digital and institutional asymmetry across regions, and a direct correlation between the number of universities and the share of employment in technological sectors. An increase in scientific activity in the East Kazakhstan and Karaganda regions indicates the emergence of new regional innovation centers. *The practical significance* of the study lies in the applicability of the findings for developing regional science and innovation policy, reducing territorial disparities, advancing mechanisms for R&D commercialization, and training human resources that meet the requirements of an innovation-driven economy.

Keywords: regional integration, R&D; innovation activity, intellectual potential, digital infrastructure, human capital, Kazakhstan regions

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ҚАЗАҚСТАН ӨНІРЛЕРІНІҢ ҒЗТҚЖ-ҒА ИНТЕГРАЦИЯСЫ ЖӘНЕ ОЛАРДЫҢ ЗИЯТКЕРЛІК ӘЛЕУЕТІН ДАМУЫ

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Аннотация. *Зерттеудің өзектілігі* Қазақстан Республикасының өңірлерін ғылыми-зерттеу және тәжірибелік-конструкторлық жұмыстар (ҒЗТҚЖ) үдерістеріне интеграциялауды күшейту қажеттілігімен айқындалады, бұл елдің зияткерлік әлеуетін арттырудың және жаңа буын мамандарын даярлаудың негізгі факторларының бірі болып табылады. Мемлекеттік реформалардың жүзеге асырылуына қарамастан, ғылыми белсенділік деңгейі, цифрлық инфрақұрылымның дамуы және білікті кадрлармен қамтамасыз етілуі бойынша елеулі аумақтық теңсіздіктер сақталуда. Астана және Алматы қалаларында ғылыми ресурстар мен зерттеу инфрақұрылымының шоғырлануы шеткері өңірлердің инновациялық үдерістерге қатысуын шектеп, олардың бәсекеге қабілеттілігін төмендетеді. *Зерттеудің мақсаты* Қазақстан өңірлерін ҒЗТҚЖ-ға интеграциялау тетіктерін теориялық-әдіснамалық тұрғыдан негіздеу және

ғылыми-инновациялық әлеуеттің кеңістіктік бөлінуіне әсер ететін факторларды бағалау болып табылады. *Зерттеу әдістері* жүйелік, институционалдық және эволюциялық-экономикалық тәсілдерге негізделіп, сондай-ақ салыстырмалы, статистикалық және құрылымдық-логикалық талдауды қамтиды. Зерттеудің эмпирикалық базасын Stat.gov.kz, OECD, UNESCO және Дүниежүзілік банк деректері құрайды. Талдау барысында ҒЗТҚЖ қарқындылығы, зерттеушілер саны, жарияланымдық белсенділік, кәсіптік білім беру ұйымдарының цифрландыру деңгейі және жоғары технологиялық секторлардағы жұмыспен қамту көрсеткіштері пайдаланылды. *Зерттеу нәтижелері* ғылыми әлеуеттің екі мегаполисте жоғары шоғырланғанын, өңірлер арасындағы цифрлық және институционалдық асимметрияның айқын екенін, сондай-ақ университеттер саны мен технологиялық секторларда жұмыспен қамтылғандар үлесі арасындағы тікелей корреляцияны анықтады. Шығыс Қазақстан және Қарағанды облыстарында ғылыми белсенділіктің өсуі жаңа өңірлік инновациялық орталықтардың қалыптасып келе жатқанын көрсетеді. *Зерттеудің практикалық маңызы* алынған қорытындыларды өңірлік ғылыми-инновациялық саясатты әзірлеуде, аумақтық теңсіздіктерді төмендетуде, ҒЗТҚЖ коммерцияландыру тетіктерін дамытуда және инновациялық экономиканың талаптарына сай кадрлар даярлауда пайдалану мүмкіндігімен айқындалады.

Түйін сөздер: аймақтық интеграция, ҒЗТҚЖ, инновациялық белсенділік, зияткерлік әлеует, цифрлық инфрақұрылым, адами капитал, Қазақстан өңірлері

Алғыс. Осы мақала ЖТН АР26198249 «Қазақстанның зияткерлік авангардын арттыру мүддесінде ҒЗТҚЖ-ға қол жеткізудегі өңірлік теңсіздікті еңсерудің инновациялық тәсілдерін зерттеу» атты ғылыми жоба аясында дайындалды

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ИНТЕГРАЦИЯ РЕГИОНОВ КАЗАХСТАНА В НИОКР И РАЗВИТИЕ ИХ ИНТЕЛЛЕКТУАЛЬНОГО ПОТЕНЦИАЛА

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Аннотация. *Актуальность исследования обусловлена необходимостью усиления интеграции регионов Республики Казахстан в процессы научно-исследовательских и опытно-конструкторских разработок (НИОКР) как ключевого фактора повышения интеллектуального потенциала страны и подготовки специалистов нового поколения. Несмотря на реализуемые государственные реформы, сохраняются значительные территориальные диспропорции в уровне научной активности, развитии цифровой инфраструктуры и обеспеченности квалифицированными кадрами. Концентрация научных ресурсов и исследовательской инфраструктуры в городах Астана и Алматы ограничивает участие периферийных регионов в инновационных процессах и снижает их конкурентоспособность. Цель исследования заключается в теоретико-методологическом обосновании механизмов интеграции регионов Казахстана в НИОКР и оценке факторов, влияющих на пространственное распределение научного и инновационного потенциала. Методы исследования основаны на системном, институциональном и эволюционно-экономическом подходах, а также включают сравнительный, статистический и структурно-логический анализ. Эмпирическую базу исследования составляют данные Stat.gov.kz, OECD, UNESCO и Всемирного банка. В анализе использованы показатели интенсивности НИОКР, численности исследователей, публикационной активности, уровня цифровизации учреждений профессионального образования и занятости в высокотехнологичных секторах экономики. Результаты исследования выявили высокую концентрацию научного потенциала в двух мегаполисах, выраженную цифровую и институциональную асимметрию между регионами, а также прямую корреляцию между числом университетов и долей занятых в технологических секторах. Зафиксирован рост научной активности в Восточно-Казахстанской и Карагандинской областях, что свидетельствует о формировании новых региональных инновационных центров. Практическая значимость исследования заключается в возможности использования полученных выводов при разработке региональной научно-инновационной политики, снижении территориальных диспропорций, развитии механизмов коммерциализации НИОКР и подготовке кадров, соответствующих требованиям инновационной экономики.*

Ключевые слова: региональная интеграция; НИОКР; инновационная активность; интеллектуальный потенциал; цифровая инфраструктура; человеческий капитал; регионы Казахстана

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Introduction. The modern knowledge-based economy reinforces the importance of human capital, innovation activity, and the ability of regions to participate in

national and global scientific and technological processes. In the context of accelerating digitalization, the effectiveness of a country's development is largely determined by the degree of distribution of scientific potential and the capacity of all regions to engage in research and development (R&D) activities (OECD, 2020; OECD, 2023). For Kazakhstan, which is characterized by significant territorial heterogeneity, this issue acquires strategic relevance: the concentration of research resources in the cities of Astana and Almaty creates a noticeable gap between the center and the periphery, limiting the potential for sustainable development (Mukhamediyev & Spankulova, 2022).

Despite ongoing government initiatives aimed at modernizing the education and science systems, the inclusion of remote regions in R&D processes remains fragmented. Regional universities and research centers face institutional, human resource, and infrastructural constraints that reduce their ability to participate in the national innovation system (Etzkowitz & Leydesdorff, 2013). At the same time, global trends - digital transformation, the expansion of remote educational and research formats, and the growing demand for high-technology skills - create new requirements for training the "next generation" of specialists (UNESCO, 2023; OECD, 2023).

Regional disparities in R&D are manifested in the persistent dominance of two national scientific centers, while most regions show low levels of research activity, limited opportunities for training qualified personnel, and insufficient digital infrastructure (OECD, 2018). This reduces the intellectual potential of regions and hinders the development of innovation ecosystems capable of generating and commercializing new knowledge (Lundvall, 2010; Foray et al., 2018). Integrating regions into the national scientific space requires a new methodological approach that considers institutional specificities and the socio-economic context of regional development.

In this context, there is a need for a theoretical and methodological justification of mechanisms for integrating Kazakhstan's regions into R&D processes, aimed at enhancing intellectual activity, developing research competencies, and preparing highly qualified specialists. This involves not only expanding access to scientific resources but also building a sustainable network infrastructure that ensures cooperation among universities, research centers, businesses, and government institutions (Höglund & Linton, 2018; Reid & Maroulis, 2017).

The purpose of this study is to determine the scientific and methodological foundations for integrating Kazakhstan's regions into national R&D processes as a factor in strengthening their intellectual potential and preparing the next generation of specialists. The research tasks include identifying key regional barriers and opportunities, conducting a comparative analysis of R&D indicators, determining the role of universities in developing human and scientific capacity, and developing approaches aimed at reducing regional disparities and improving the effectiveness of innovation policy.

Literature Review. Research on regional development in science and innovation

is grounded in a set of conceptual approaches that define the role of regional innovation systems (RIS) and the conditions for building scientific potential. Classical studies on national innovation systems emphasize the importance of interaction among education institutions, research organizations, businesses, and government bodies in generating knowledge and disseminating technologies (Lundvall, 2010). According to the “triple helix” model of university–industry–government relations, synergy among key actors forms the foundation for innovation dynamics and economic transformation (Etzkowitz & Leydesdorff, 2013). This model was later extended to the quadruple helix, incorporating civil society - an especially relevant aspect for peripheral regions with limited institutional networks (Höglund & Linton, 2018).

Contemporary international research confirms that the effectiveness of regional innovation systems depends on the quality of the institutional environment, the level of human capital, and the availability of specialized infrastructure (OECD, 2020; OECD, 2023). Regions with low R&D activity are typically characterized by a shortage of research personnel, weak integration of universities with industry, and the absence of technology transfer centers (OECD, 2018). These observations align with the conclusions of Foray, Morgan and Radošević, who argue that successful implementation of smart-specialisation strategies requires concentrating resources on narrow fields aligned with unique regional strengths (Foray et al., 2018).

The challenges of peripheral regions in science and innovation are highlighted in the works of both Kazakhstani and international scholars. Mukhamediyev and Spankulova (2022) demonstrate the relationship between innovation activity, the efficiency of regional human resources, and economic growth. The authors note significant differences between central and peripheral regions caused by uneven digital infrastructure and the lack of sustainable university–industry collaboration models. Similar conclusions can be found in Clarke, Jones and Lacy (2015), who emphasize the role of educational investment and workforce quality in building regional competitiveness.

International practice shows that under spatial differentiation, key tools for regional inclusion involve platform-based solutions, digital remote-access services, and enhanced support for research mobility (UNESCO, 2023; EU4Education, 2023). According to OECD (2023), regions integrated into digital scientific networks and cloud-based collaborative research platforms demonstrate higher levels of knowledge commercialization and better training outcomes for technologically advanced sectors. At the same time, experts stress that building a digital ecosystem is impossible without systematic investments in teacher training, curriculum modernization, and the development of educators’ competencies (OECD, 2023; UNESCO, 2023).

Another line of research focuses on the development of R&D commercialization instruments. Studies by Kenzhaliyev et al. (2021) and OECD reports (R&D intensity case studies, 2020) show that the absence of local venture capital funds, technology transfer offices, and sustainable financing mechanisms significantly weakens regions’ ability to implement research outcomes. Reid and Maroulis (2017) emphasize that the transition from strategy to implementation is possible only in the presence of

a comprehensive monitoring framework that incorporates input–output–outcome–impact metrics.

In addition, studies of European and Asian regions demonstrate that limited access to high-speed internet, digital laboratories, and remote learning tools is one of the main barriers to preparing the next generation of specialists (OECD, 2023; UNESCO, 2023). For Central Asian countries, digital infrastructure becomes a decisive factor for developing human capital and reducing regional disparities.

Overall, the literature indicates that integrating peripheral regions into national R&D processes requires a combination of institutional development, modernization of the educational environment, digital transformation, and support for commercialization. Academic publications underline the need to move away from a centralized model of research resource allocation toward more networked, inclusive, and regionally adaptive mechanisms capable of stimulating the growth of intellectual potential and forming a competitive workforce.

Materials and methods. The methodological framework of the study is based on systemic, institutional, and evolutionary-economic approaches, which together make it possible to comprehensively evaluate the processes of integrating Kazakhstan's regions into research and development (R&D) activities. The systemic approach enables the consideration of education, science, innovation, and employment as interconnected elements of a unified model for shaping regional intellectual potential (Lundvall, 2010; OECD, 2023). The institutional approach allows for assessing the role of universities, research centers, businesses, and government structures in building regional innovation ecosystems (Etzkowitz & Leydesdorff, 2013; Höglund & Linton, 2018). The evolutionary-economic approach is applied to explain the accumulation of knowledge that affects the ability of regions to adapt to technological changes.

The empirical base of the research consists of statistical data from the Bureau of National Statistics of the Republic of Kazakhstan, OECD, UNESCO, and the World Bank, as well as regional indicators of innovation activity and infrastructure for 2023–2024 (Stat.gov.kz, 2024). The dataset includes the number of researchers by region, R&D intensity, expenditure on research and development, the number of universities and their publication activity, characteristics of the digital infrastructure of vocational education institutions, and metrics related to employment in high-tech sectors.

Results. The results of the study reveal a pronounced regional asymmetry in research and innovation activity across Kazakhstan. Analysis of statistical data from the Bureau of National Statistics of the Republic of Kazakhstan (2023–2024) demonstrates that scientific potential is predominantly concentrated in the two largest urban agglomerations - Astana and Almaty. These regions lead in the number of researchers, the share of enterprises engaged in R&D, and the volume of funding allocated to scientific activities.

Table 1 presents key indicators of innovation activity across major regions of the country. The data illustrate a significant gap between the leading scientific centers

and the peripheral regions, where less than 3% of enterprises are involved in research activities.

Table 1. Innovation Activity by Regions of Kazakhstan (Stat.gov.kz, 2023–2024)

Region	Share of Enterprises Engaged in R&D (%)	Number of researchers	R&D Expenditures (billion KZT)
Almaty city	22.5	10,450	210.3
Astana city	18.9	8,130	182.7
Karaganda Region	11.2	5,420	97.1
East Kazakhstan Region	9.3	4,870	84.5
Ulytau Region	2.8	740	9.2

Source: Stat.gov.kz, 2023–2024

Additional analysis of key structural characteristics of R&D is presented in Table 2, which compares the number of researchers, the number of universities, publication activity, and the prevalence of online programs across regions.

Table 2. Key R&D Indicators by Regions of Kazakhstan (2023–2024)

Region	Number of researchers	Number of universities	Publications (Scopus, 2023)	Share of Online Programs (%)
Almaty city	10,450	38	11,200	78
Astana city	8,130	23	8,540	82
Karaganda Region	5,420	10	2,450	64
East Kazakhstan Region	4,870	7	1,120	58
Aktobe Region	3,720	6	670	49
Kostanay Region	2,650	5	—	—
Zhambyl Region	1,780	4	—	—
Ulytau Region	740	2	—	—

Source: Stat.gov.kz, 2023–2024 (authors' calculations).

The data presented in Table 2 confirm a persistent gap between central and peripheral regions. Almaty and Astana together account for more than half of all scientific publications in the country. Meanwhile, Ulytau, Zhambyl, and Kostanay regions demonstrate no measurable publication activity, indicating a critical shortage of scientific infrastructure.

Graphical analysis (Figure 1) illustrates the territorial concentration of research activity: Astana accounts for 28%, Almaty for 24%, and Karaganda for 15%. This distribution aligns with international findings on the dominance of agglomeration effects in innovation activity (Lundvall, 2010; Mukhamediyev & Spankulova, 2022).

The correlation between the number of universities in a region and the share of employment in technical sectors (Figure 2) reveals a pronounced positive relationship. Regions with a more developed university network show higher employment rates of graduates in high-tech industries, confirming the key role of universities in building intellectual potential (Etzkowitz & Leydesdorff, 2013; OECD, 2020).

Correlation between Number of Universities and Employment in Technical Sectors (Kazakhstan, 2024)

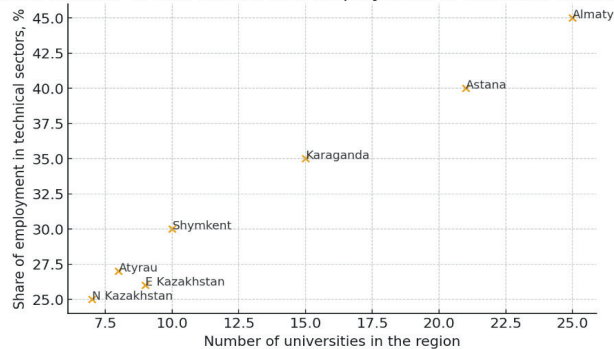


Figure 1 - Correlation between the Number of Universities and the Share of Employment in Technical Sectors in Kazakhstan, 2024

Particular attention is given to the analysis of the digital infrastructure of technical and vocational education and training (TVET), which represents a crucial factor in preparing the next generation of specialists. Table 3 presents regional indicators of access to high-speed internet, the use of digital learning platforms, and the level of digital competencies among teachers.

Table 3. Level of Digital Infrastructure in TVET Institutions by Regions of Kazakhstan, 2024

Region	Share of Colleges with High-Speed Internet (%)	Use of LMS (%)	Digital Competencies of Teachers (0–100)
Almaty city	96	92	88
Astana city	94	90	85
Karaganda Region	85	78	73
East Kazakhstan Region	82	75	70
Turkestan Region	74	60	58
Zhambyl Region	71	58	55
Mangystau Region	76	65	62
Kostanay Region	80	72	67
Source: compiled based on data from the Bureau of National Statistics of the Republic of Kazakhstan, UNESCO, UNEVOC (2024).			

- The obtained data confirm three key findings of the study:
1. A strong territorial concentration of scientific potential, where Almaty and Astana accumulate the majority of the country’s research resources.
 2. Growing scientific activity in certain industrially developed regions, such as East Kazakhstan and Karaganda.
 3. Significant digital differentiation across regions, which directly affects the quality of specialist training and the ability of institutions to participate in R&D activities.
- These results form the basis for developing mechanisms to integrate regions into



the national scientific system and highlight the need to reduce digital and institutional disparities.

Discussion. The findings of the study confirm a significant territorial heterogeneity in Kazakhstan's scientific and innovation development, consistent with international research highlighting the spatial concentration of knowledge and technology within major urban agglomerations (Lundvall, 2010; OECD, 2020). The dominance of Astana and Almaty in the national R&D structure reflects a typical "center-periphery" pattern, in which innovation processes are concentrated in regions with advanced infrastructure and high levels of human capital. This aligns with the "triple helix" model of university-industry-government interaction (Etzkowitz & Leydesdorff, 2013), which posits that major scientific centers generate a critical mass of knowledge and create favorable conditions for commercialization.

At the same time, the positive dynamics observed in East Kazakhstan and Karaganda Regions support the arguments of smart specialisation studies (Foray et al., 2018), suggesting that peripheral regions can develop growth points when resources are focused on locally embedded competencies. The increase in publication activity and industrial development in these regions indicates the potential formation of new innovation clusters beyond the major metropolitan areas.

Digital infrastructure emerged as one of the key determinants of regional capacity to participate in R&D and to prepare the next generation of specialists. Regional differences in access to high-speed internet, the use of LMS platforms, and the digital competencies of teachers correspond with UNESCO and OECD findings that the digital environment constitutes not only a technological factor but also a structural prerequisite for the modernization of educational systems (UNESCO, 2023; OECD, 2023). Insufficient digitalization in TVET institutions in Zhambyl, Turkestan and several western regions undermines their competitiveness and limits opportunities for participation in network-based scientific activities.

An important finding is the positive correlation between the number of universities and the share of employment in high-tech sectors. This aligns with the arguments of Mukhamediyev and Spankulova (2022), who show that human capital and innovation activity are strengthened when supported by a developed educational ecosystem. Universities fulfil not only educational but also research, entrepreneurial and social functions, forming local actor networks and serving as regional development nodes.

However, the analysis reveals several systemic constraints that hinder regional integration into the national innovation system. First, institutional fragmentation persists - characterized by weak linkages between universities, enterprises and local authorities - which is consistent with the conclusions of Höglund and Linton (2018). The absence of technology transfer centers and the low level of R&D commercialization in peripheral regions corroborate the findings of Kenzhaliyev et al. (2021) and OECD R&D intensity case studies, demonstrating that the lack of venture financing and innovation infrastructure substantially reduces returns on research investment.

Second, the low mobility of researchers limits knowledge diffusion and the

formation of sustainable collaboration networks. International experience shows that mobility is one of the most effective mechanisms for integrating regions into global knowledge chains (Reid & Maroulis, 2017); yet in Kazakhstan it remains constrained by limited funding and the lack of mobility programs specifically designed for peripheral regions.

Third, the persistence of the digital divide significantly affects the quality of human capital development and the capacity of regions to engage in R&D. This is particularly critical in the context of the Fourth Industrial Revolution, where proficiency in digital tools, analytical platforms and remote laboratory systems becomes a fundamental component of professional training (UNESCO, 2023).

Overall, the results demonstrate that integrating Kazakhstan's regions into national scientific and research activity requires a transition from centralized allocation of resources toward a multi-level, network-based model of regional development. Such a model should incorporate:

1. The development of scientific and digital infrastructure;
2. Strengthening universities as local knowledge hubs;
3. Building mechanisms for R&D commercialization;
4. Increasing researcher mobility;
5. Scaling smart specialisation practices.

Thus, the findings align with international evidence and confirm that sustainable growth of Kazakhstan's intellectual potential is achievable only through systemic regional support, expanded access to digital resources, and the formation of an integrated innovation ecosystem.

Conclusion The conducted research has made it possible to identify the key patterns and barriers affecting the integration of Kazakhstan's regions into scientific and innovation activities, as well as to determine the mechanisms for strengthening regional intellectual capacity in the context of digital transformation. Based on statistical analysis, comparative assessments of regional disparities, and theoretical–methodological frameworks, the following main conclusions can be drawn:

Kazakhstan is characterized by a pronounced territorial asymmetry in R&D activity, where scientific potential and human resources are concentrated primarily in Astana and Almaty. Most peripheral regions exhibit low research activity, limited digital infrastructure, and a shortage of qualified specialists. This highlights the need to transition toward a more inclusive model of innovation-driven development.

Universities act as key drivers in shaping regional intellectual potential, influencing employment in technical sectors, publication output, and the ability of regions to participate in R&D. Strengthening university ecosystems, expanding research-training programs, and establishing technology transfer centers are essential strategic directions.

Digital infrastructure is identified as a strategic factor in modernizing workforce preparation. Strong regional disparities in access to high-speed internet, LMS platforms, cloud services, and teachers' digital competencies significantly affect access to modern educational technologies and the ability of colleges and universities to participate in network-based scientific projects.

Effective integration of regions into the national innovation system requires a comprehensive institutional approach, including the development of scientific infrastructure, increased researcher mobility, creation of R&D commercialization mechanisms, and implementation of smart-specialisation strategies tailored to unique regional competencies.

The practical significance of the study lies in its potential application for shaping regional science development strategies, improving educational programs, planning state support measures for R&D, and modernizing the digital infrastructure of professional education.

Future research may focus on:

- developing models for assessing the effectiveness of regional R&D integration;
- constructing regional indices of scientific and innovation development;
- studying the specifics of cooperation between universities and industrial clusters;
- designing mechanisms to support researcher mobility and digital platforms for remote laboratories;
- evaluating the impact of smart specialisation on the emergence of new growth points in peripheral regions.

Overall, the results of the study confirm that the integration of Kazakhstan's regions into scientific research activities is a key prerequisite for strengthening the country's intellectual potential and preparing a new generation of highly qualified specialists capable of effective participation in the innovation economy.

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