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The Study of the Perception by Kazakhstani Universities of Tools for Supporting Research Activities

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ABSTRACT

Globally, universities play a key role in developing and commercializing new technologies through research and development (R&D) support. However, Kazakhstan faces several challenges, including financial constraints, outdated scientific infrastructure, and weak links between universities and industry. This study aims to provide a comprehensive analysis of the key factors affecting R&D support in Kazakhstan and to identify the main financial, infrastructural, and institutional challenges that hinder the efficient use of R&D resources. The study used bibliometric data analysis using VOSviewer and qualitative interview analysis using Atlas.ti software. Primary data were collected through interviews with experts from various higher education institutions in Kazakhstan. The analysis focused on aspects such as R&D financing, the state of scientific infrastructure, interaction with business, and barriers for young scientists. The results of the study show that financial constraints have a significant impact on infrastructure upgrades and project deadlines. Business integration correlates positively with R&D commercialization (r = 0.848) but remains weak due to structural barriers. Budgetary inflexibility hinders efforts to modernize infrastructure and digitize processes, while insufficient support for young scientists increases the problem of staff retention. Expert assessments demonstrate a negative perception of infrastructure accessibility (-0.421) and predictability of funding among most academic positions. Future research should focus on developing adaptive financing models and studying the international interaction experience between universities and industry to strengthen the innovation ecosystem of Kazakhstan.

KEYWORDS: Science, Financing of Science, Infrastructural Support, Universities, Digitalization, Innovation Ecosystem, Strategic Priorities

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Исследование восприятия казахстанскими ВУЗами финансовых инструментов поддержки НИОКР

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АННОТАЦИЯ

В глобальном масштабе университеты играют ключевую роль в разработке и коммерциализации новых технологий посредством поддержки научно-исследовательской деятельности (НИОКР). Однако Казахстан сталкивается с рядом проблем, включая финансовые ограничения, устаревшую научную инфраструктуру и слабые связи между университетами и индустрией. Целью данной статьи является проведение комплексного анализа ключевых факторов, влияющих на поддержку НИОКР в Казахстане, а также на выявление основных финансовых, инфраструктурных и институциональных барьеров, препятствующих эффективному использованию ресурсов НИОКР. В рамках данного исследования использовались методы библиометрического анализа данных с применением программы VOSviewer, а также качественного анализа интервью с использованием Atlas.ti. Основные данные были собраны путем проведения интервью с экспертами из различных высших учебных заведений Казахстана. Анализ был сосредоточен на таких аспектах, как финансирование НИОКР, состояние научной инфраструктуры, взаимодействие с бизнесом и барьеры для молодых ученых. Результаты исследования показывают, что финансовые ограничения оказывают значительное влияние на модернизацию инфраструктуры и соблюдение сроков реализации проектов. Интеграция бизнеса положительно коррелирует с коммерциализацией НИОКР (r = 0,848), однако остается слабой из-за структурных барьеров. Бюджетная негибкость препятствует модернизации инфраструктуры и цифровизации процессов, в то время как недостаточная поддержка молодых ученых усиливает проблему удержания кадров. Оценки экспертов демонстрируют негативное восприятие доступности инфраструктуры (-0,421) и предсказуемости финансирования среди большинства академических позиций. Будущие исследования должны быть направлены на разработку адаптивных моделей финансирования, а также изучение международного опыта взаимодействия университетов и индустрии для укрепления инновационной экосистемы Казахстана.

КЛЮЧЕВЫЕ СЛОВА: наука, финансирование науки, инфраструктурная поддержка, университеты, цифровизация, инновационная экосистема, стратегические приоритеты

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INTRODUCTION

Globally, universities serve as key hubs for developing and commercializing new technologies through strengthening research and development (further - R&D) support. Countries such as the USA, Germany, and South Korea have developed strong mechanisms for integrating research in universities with industry needs to commercialize R&D results effectively. Such cooperation becomes the engine for developing and promoting higher educational institutions' R&D activity commercialization, developing national innovation ecosystems, and contributing significantly to GDP. In Europe, the significant role of R&D activity is promoted through collaborative research projects such as the Horizon Europe framework for R&D activities co-financing.

The interaction between the academic environment, industry, and government institutions is considered the most important factor in contributing to scientific progress and creating competitive economies. Effective R&D support mechanisms, including financing models, infrastructure modernization, and digitalization, form the basis for increased scientific productivity and the transformation of knowledge into economic outcomes (Lewis, 2000; Cabrer-Borras & Serrano-Domingo, 2007). Research shows that various R&D financing models have advantages and disadvantages, such as broad-block funding, competitive grants, and targeted investments in priority areas (Geuna & Muscio, 2009; Perkmann & Walsh, 2007; Cai & Liu, 2015). Despite significant public and private investment in science and innovation systems worldwide, challenges remain, particularly in countries with transition economies. Limited funding, outdated scientific infrastructure, and weak integration of fundamental and applied research hinder the modernization of the scientific system and increase the country's international competitiveness (Orynbasarova et al., 2017; Dnishev et al., 2022).

However, in Kazakhstan, some challenges necessitate targeted support for R&D activities in universities. According to national statistics, the share of gross domestic expenditure on research and development (GERD) relative to GDP remains rather low. In 2023, R&D expenditure in Kazakhstan accounted for only 0.13% of GDP, significantly below the OECD average of 2.68%. Moreover, universities face limited opportunities to finance research independently due to low internal expenditures on R&D activities. The share of higher education and science in Kazakhstan's GDP also remains modest. First of all, there is a gap in the country's ability to utilize the economic potential of its research institutions fully. Therefore, financial mechanisms, flexible budgetary processes, and strengthened industry-university linkages are of high importance for R&D support in the higher education sector. Moreover, science and education are one of the drivers of human capital development and technological progress. In addition, there are no scientific papers in this literature aimed at identifying barriers to effective R&D support in Kazakhstan.

Addressing the barriers that impede the effectiveness of R&D support requires a complex approach to unlocking Kazakhstan's research ecosystem's full economic potential. This study aims to provide a comprehensive analysis of the key factors affecting R&D support in Kazakhstan and identify the main financial, infrastructural, and institutional challenges that hinder the efficient use of R&D resources. This work seeks to fill the existing scientific gap and offer recommendations aimed at improving the level of development of science and scientific infrastructure.

LITERATURE REVIEW

Research in the field of R&D support highlights the importance of interaction between academic and industrial environments in ensuring sustainable development. Governments, the private sector, and international organizations play a significant role in funding science, but mechanisms and outcomes vary widely. Scientists point out the significance of interregional networks and public investment as key factors in providing access to R&D and stimulating innovative potential (Lewis, 2000; Cabrer-Borras & Serrano-Domingo, 2007). In addition, several researchers have emphasized the importance of various factors for regional innovation. These include the size of the innovation network, public investment in R&D, and the relationship between universities (Perkmann & Walsh, 2007; Cai & Liu, 2015).

Some scientific studies have focused on R&D financing as one of the key factors influencing the success of scientific projects (Segooa & Kalema, 2019; Yu & Liu, 2017). Liefner (2003) further highlights that performance in research can improve with adequate funding and proper incentives, provided that research teams possess the necessary skills. However, Tammi (2009) suggested that excessive industrial funding may negatively affect research performance due to factors such as a focus on short-term objectives, biased resource allocation, or limitations on disseminating knowledge. Public funding is a cornerstone of scientific research, often justified by its significant societal benefits, including advancements in health and contributions to economic growth (Szarowská, 2018; Weinryb et al.,

2018). It remains the primary source of income for public universities, but growing demands and limited resources have prompted governments to explore alternative funding methods and encourage universities to diversify their income sources. However, the ongoing crisis of the welfare state has intensified concerns about the sustainability of relying heavily on public funding for higher education. In response, many Western governments have attempted to curb the growth of public spending while seeking innovative ways to support the financial needs of universities (Teixeira & Koryakina, 2013). In Kazakhstan, similar problems lead to insufficient modernization of scientific infrastructure and the limitation of large-scale research.

Scientific infrastructure is an essential prerequisite for successful R&D. However, the lack of modern material and technical resources limits the ability of universities to conduct advanced research. Minguilla and Thelwall (2015) emphasized the importance of infrastructure modernization, pointing to the need for investment in equipment and the creation of specialized research centers to improve scientific performance. Wang et al. (2018) considered how to incentivize productive and innovative research best while effectively documenting the returns on public funding. They highlight three funding models: broad block funding for research (e.g., the German model), competitive project-level grants (e.g., the US model), and university-level competition for differential block funding (e.g., the UK model). For example, the American model of competitive financing at the project level focuses on short-term achievements and high results, but this approach has a downside, including significant administrative costs for preparing applications and unstable financing (Geuna & Muscio, 2009). In turn, the British model allows for the effective allocation of resources depending on the quality and significance of the scientific activity. However, it also leads to discussions about the increased burden on researchers and university administration (Whitley & Glaser, 2014). Furthermore, Germany's broad block financing characteristic contributes to stability and long-term research planning, allowing universities to focus on strategic priorities. However, this model may reduce competitiveness due to a lack of fierce competition for resources (Wagner et al., 2015).

Many public research councils and foundations have more actively directed their grant allocations towards specific priority areas and research challenges. While these choices are occasionally based on the intellectual importance and potential of the research, they are increasingly aligned with public policy goals set by governments (Whitley et al., 2018). Di Carlo et al. (2019) claimed that using the ratio of income generated by universities through competitive research grants, contracts, and tuition fees can improve universities' financial capacity. In contrast, Laird (2020) critiques the model for its inability to evolve, which has resulted in an imbalance that prioritizes large-scale research programs over smaller, potentially transformative projects. Moreover, he emphasized that universities have overextended their research capacities, leading to inefficiencies and fiscal instability.

Many scientific studies emphasize the importance of university cooperation as one of the critical factors contributing to the commercialization of scientific research and innovative development. This process is vital in transforming knowledge and technology from the academic environment into economic value, strengthening national economies' competitiveness (Etzkowitz & Leydesdorff, 2000). However, research points out many challenges and limitations associated with implementing such partnerships. According to Percamn et al. (2012), many projects face difficulties due to a lack of sustainable partnerships. Researchers note that imperfections in national innovation policies can increase constraints at the micro-level, particularly in countries with transition economies (Muscio, 2013). Industry funding focuses on applied research with commercial potential. Companies finance university research when they benefit from it (Perkmann et al., 2013; Quapp & Holschemacher, 2016).

Digitalization is considered an essential tool for modernizing the scientific field. It provides new opportunities to improve resource management efficiency. Many universities, especially those in countries with limited science budgets, face a lack of funds to purchase and maintain digital infrastructure (Knowles et al., 2021). Many research teams are not ready to implement new technologies due to insufficient digital literacy (Ali et al., 2023). In addition, the complexity of integrating new technologies into existing university and research centre processes also hinders widespread adoption of digital solutions. Using cloud technologies and digital databases, such as Scopus or WoS, simplifies access to information and reduces the need for expensive material resources (Stukalova & Guskov, 2016). The financial support mechanism for R&D, as described by Hreben et al. (2019), involves several critical components designed to optimize the allocation and use of budgetary funds. A key aspect is the control mechanism, which links funding allocation to research performance through tools such as financial control and IT auditing. Implementation relies on IT auditing to analyze research data, as well as international rankings and publication metrics to assess

results. Addressing these issues through systematic IT auditing and adherence to global standards could significantly improve research quality.

In the context of Kazakhstan, the relevance of choosing an effective financing model is due to the need to modernize the scientific system and increase its international competitiveness. One of the key problems is the limited amount of funding, which leads to weak mobility of scientists and insufficient integration of fundamental research into applied research. Thus, many studies by Kazakh scientists are mainly aimed at assessing the current state of the research infrastructure, the level of R&D funding, and the analysis of factors influencing innovation activity (Orynbassarova et al., 2017; Dnishev et al., 2022; Doshmanova et al., 2024).

A literature review has shown the existence of various R&D support mechanisms and their importance for innovative development and economic growth. The analysis focuses on the critical role of the state, the academic community, and business in stimulating science and the importance of financing. Investments in digitalization and the creation of research centers play a key role in increasing scientific productivity and competitiveness on the international stage. Digital tools like cloud technologies and international databases like Scopus and Web of Science open new possibilities to improve research efficiency. Kazakhstan needs to find an effective funding model to modernize the scientific system and enhance international competitiveness, which requires further study.

The review of the aforementioned scientific research identified various approaches to R&D support and their significance for the national economy. In general, several studies focused on the significance of government support for academic communities through government funding. Other studies highlighted the role of investment in digitalization and the establishment of research centers as crucial factors contributing to scientific productivity growth and enhancement of international competitiveness. It should be noted that digital tools and ranking databases are essential. For Kazakhstan, finding an optimal financing model for modernizing its scientific system and enhancing its position on the global stage remains a pressing task, which necessitates further theoretical and empirical investigation.

This paper used the Scopus database to select key variables that influence R&D development. As a result, the analysis of scientific documents covered the period from 2010 to 2024. However, the greatest intensity of research materials was noted during the period from 2017 to 2021. The sample results showed that journal articles accounted for the largest share of publications, with a total number exceeding 1,500 documents; scientific conference materials were less than 300.

Figure 1 shows cluster networks of bibliometric materials based on the use of VOSviewer.

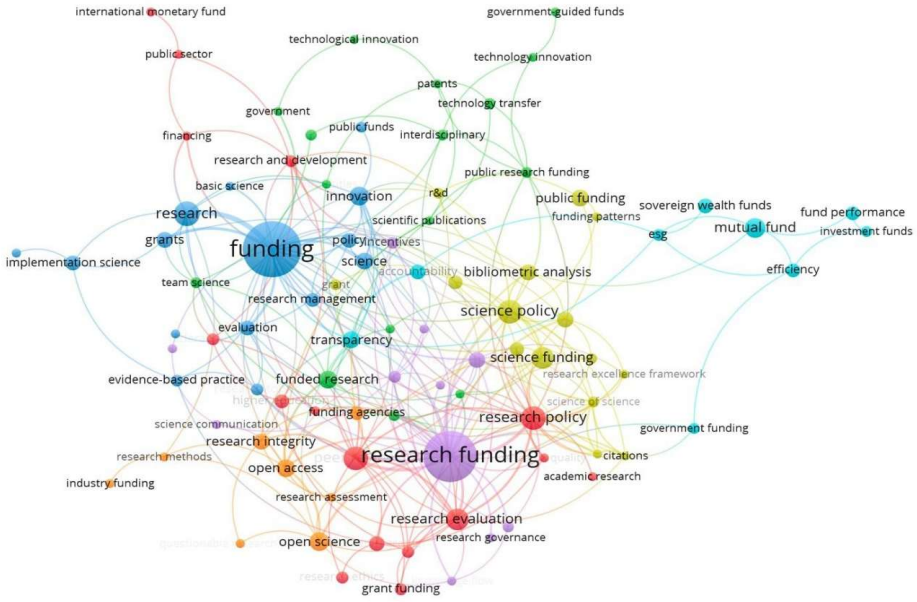

Figure 1. Bibliometric network map of keywords

Source: compiled by the author based on VOSviewer

Type 1 keywords were used within the broader context of research funding to retrieve meta-information from Scopus. The query included terms such as {science}, {research}, {funding}, {financial tool}, {university}, {R&D}, {financial instruments}, and {higher education}. In the network visualization results, elements are represented as labeled circles, where the size of the labels indicates the weight of connections between key terms. The analysis identified six distinct cluster groups, colour-coded for clarity: (1) blue cluster: funding; (2) green cluster: innovation and technology; (3) red cluster: research and development; (4) yellow cluster: science policy and public funding; (5) orange cluster: open science and integrity; (6) purple cluster: research evaluation and policy.

The visualization is a bibliometric network map illustrating the relationships among various topics related to science and R&D, representing thematic groupings derived from the relationships and density of keywords. The primary nodes are {funding} (blue) and {research funding} (purple), which serve as the foundation for all clusters and highlight their central role in the system of scientific funding. The yellow cluster, {science policy}, also holds significant importance due to its connection with government policies and public funding. The blue cluster focuses on the overarching theme of funding and grant support for scientific research. It emphasizes issues such as research management, transparency, and the practical implementation of scientific projects. The purple cluster is dedicated to research funding, with a particular focus on evaluation, ethical integrity, and openness. It highlights mechanisms for assessing research quality and ensuring the accessibility of results to a broader audience. Specific nodes, such as {mutual fund} and {efficiency}, are located on the periphery, reflecting their specialized nature compared to the central themes. The visualization demonstrates that funding plays a pivotal role in connecting innovation, policy, and research quality evaluation. Additionally, topics related to accountability, open science practices, and governance emerge as critical factors influencing the efficiency and transparency of research funding processes.

RESEARCH METHODS

The conducted analysis was based on the application of software for qualitative data analysis. First of all, Atlas. ti a tool for qualitative data analysis was applied for processing interviews and involved a coding process. The main task was to process large volumes of textual information and to ensure transparency and flexibility. Based on the analysis, key topics were identified for further research. In order to set the focus on coding and subsequent stages of the analysis, the objectives and research questions were developed. Next, a set of codes was developed, in addition to pre-defined categories, as the result of analyzing theoretical concepts and anticipated themes identified in the literature. As the main reference to the research design, research articles describing qualitative approaches were used as reference sources, including the work of Perkmann et al. (2013), Quapp and Holschemacher (2016), and Knowles et al. (2021).

The coding process used an inductive-deductive approach, with some codes and categories pre-defined and others emerging during the analysis based on new data and their interpretation. In Atlas. ti, a coding structure was created that included both broad, general categories and narrower, more detailed themes (Table 1).

Table 1. Interviews analysis results

Coding	Description and rationale
State funding of R&D	Effectiveness and factors of public funding of R&D
Transparency and improvement	Transparency in public administration is important, as it supports codes related to R&D.
Flexibility in spending	Need for flexibility in spending to adapt to changes in R&D management.
Corruption risks	The impact of corruption on economic development applies to the analysis of corruption risks in R&D.
Private funding of R&D	Role of private funding and its limitations in academic research.
Commercialization of R&D	Barriers and opportunities for commercialization of R&D
Business partners	Role of business partners and their influence on university research priorities.
Infrastructure solutions	Need for infrastructure investments to support R&D.
Opportunities for young scientists	Limitations and opportunities for young scientists in academia, emphasizing the need for support.

Requirements for publications	Assessment of publication requirements and their impact on academic careers.
Retention of specialists	The difficulties of retaining specialists in a highly competitive academic environment.
Revision of requirements	Need to revise requirements to adapt the scientific environment to modern conditions.
Interdisciplinary research	The role of an interdisciplinary approach to R&D and its impact on scientific progress.
Internal funding	Motivation of universities for internal funding to support R&D.
International funding	Role of international sources for R&D support.
Adaptation of foreign models	Role of adapting successful foreign models to the local context.
Digitalization of processes	The impact of digitalization on R&D processes emphasizes the need to adapt to digital technologies.
Scientific infrastructure	The importance of a developed scientific infrastructure to ensure effective R&D.

Note: complied based on Perkmann et al. (2013); Quapp & Holschemacher, 2016; Knowles et al. (2021)

After the development of factors and coding, the variables were categorized and grouped into larger groups to help structure the data and identify key areas of analysis. Based on the approach described in the work of Levins and Silver (2007). There were interviewed 15 experts from 15 higher educational institutions, including research organizations (such as South Kazakhstan University, Kazakh National University named after Al-Farabi, and the Institute of Geography), among others. The respondents' selection was based on their roles spanning key areas of research management and academic leadership. They hold academic and administrative positions (professors, associate professors, deans, department heads, and laboratory heads), providing a complex perspective on the factors of R&D support in universities. The respondents' positions were applied as the main categorical factors for the analysis provision. They were coded as 1 – Associate Professor, 2 – Head of Department, 3 – Professor, and 4 – Dean/ Laboratory Head, ensuring a structured approach to examine differences across respondent roles. The respondents were 37 to 67 years old, with R&D management experience varying from 5 to 30 years, reflecting a well-balanced mix of mid-career and senior-level professionals. The rationale for selecting 15 respondents was to ensure the inclusion of experts from various universities with diverse academic, administrative, and research backgrounds. This diversity provides a holistic view of the barriers and opportunities within Kazakhstan's R&D system, offering insights from a broad spectrum of institutional and professional perspectives.

The research comprised four main stages for deeper building proposition analysis (Figure 2).

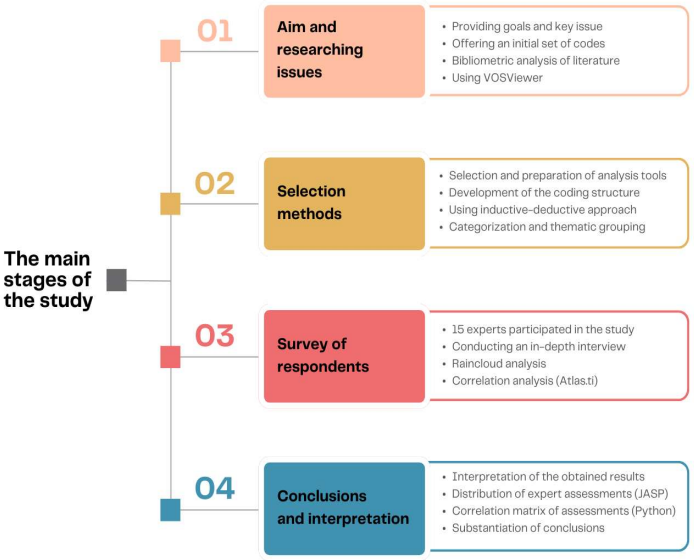

Figure 2. The steps of conducting scientific research

The study was conducted in several successive stages, each with a clear methodological basis and analytical focus. The initial stage was the definition of goals and research issues, which allowed us to lay a theoretical foundation and propose an initial set of codes. Bibliometric analysis of literature using specialized software was used to systematize the information. Analytical tools were selected and prepared at the next stage, providing a structured data processing approach. The coding process was based on an inductive-deductive approach, making it possible to combine predefined theoretical categories with topics that arise while analyzing new data. Data was collected through in-depth interviews with experts from higher education institutions and research organizations. Subsequently, the data were subjected to in-depth analysis, including visualization of the distribution of factors and assessment of their relationship using correlation analysis. Raincloud were used to visualize the distribution and density of key R&D support and negative factors across different categories. Correlation matrix for propositions check was conducted to analyze the strength and direction of relationships between key factors influencing R&D support. At the final stage, the results were interpreted, taking into account the theoretical context and empirical data. The main purpose was to detect interdependencies between financial constraints, business integration, scientific infrastructure, and process digitalization, helping to confirm or refute theoretical assumptions about their interactions and impacts on research performance.

RESULTS

The analysis explores the distribution of key factors influencing project implementation based on academic positions. Five core dimensions were analyzed to identify variations in perception of these factors across academic roles and uncover underlying issues critical to effectively realizing research and development (R&D) projects.

Table 2. Factor loadings for key R&D support and barrier factors

Variable	Primary split factor	n	Lower whisker	25th percentile	Median	75th percentile	Upper whisker
Infrastr_Support_1	1	7	-0.421	-0.421	-0.421	-0.421	-0.421
	2	4	-0.421	-0.421	-0.421	0.131	0.131
	3	5	-0.421	-0.421	-0.421	-0.421	-0.421
Financial_1	1	7	0.869	0.869	0.869	0.869	0.869
	2	4	-2.321	-2.321	0.869	0.869	0.869
	3	5	0.869	0.869	0.869	0.869	0.869
Financial_2	1	7	-0.877	-0.877	-0.877	-0.877	-0.877
	2	4	-0.877	-0.877	-0.877	-0.217	-0.217
	3	5	-0.877	-0.877	-0.877	-0.877	-0.877
Interdiscip_Adap_1	1	7	0.336	0.336	0.336	0.336	0.336
	2	4	0.336	0.336	0.336	0.336	0.336
	3	5	0.336	0.336	0.336	0.336	0.336
Business_Integ_1	1	7	0.478	0.478	0.478	0.478	0.478
	2	4	-0.986	-0.701	-0.065	0.478	0.478
	3	5	-3.155	-0.986	0.478	0.478	0.478

Note: complied based on calculations

Infrastructure and Support – there were observed low scores in majority of the positions. In particulsr, the scores for Professors and Associate Professors (-0.421), score reflects dissatisfaction with infrastructure availability and existing support mechanisms. Nevertheless, according to the scores for Heads of Departments, there was observed a slight deviation, which could be explained as this group perceives more favorable conditions. Revealed results confirmed that there exists unequal access to infrastructure within various hierarchical levels. In this case, management roles, including department heads, are expected to have accessibility and opportunity to make decisions in resources distribution.

Financial Factors 1 – factors explains the perceptions of general financial flexibility and availability of financial support. The results for Associate Professors and Professors showed that they are satisfied with available financial support for their projects, assuming, based on stable positive values (0.869). Notwithstanding, the results range (from -2.321 to 0.869) for Heads of Departments, showed that there are mixed experiences, with financial challenges and restruictions for this group. As revealed, there are dual responsibilities for managing positions, which include the duties related to both academic and administrative tasks. Thus, it could draw unfavorable environment and therefore have more direct impact of funding irregularities.

Financial Factors 2 – set of factors reflects a narrower aspect of financial conditions. Both Professors and Associate Professors reported negative values (-0.877), which revealed existance of systemic issues with funding predictability or sufficiency for project implementation. In contrast, thyere was observed a slight improvement for Heads of Departments scores (-0.217). In other words, despite existing challenges, there is access to alternative financial sources or mechanisms.

A relatively stable understanding of the Interdisciplinarity and Adaptation factor was observed in all positions. Therefore, cross-disciplinary and adaptation to emerging research environments with 0.336 consistent values. It must be regarded, that stability also reflects stagnation. Therefore, existing mechanisms,which supported interdisciplinarity still need to be utilized or more supported across all managing positions.

The Business Integration factor showed there was a prominent variability in scores. Professors and Associate Professors showed positive scores (0.478). On the ccontrary, Heads of Departments report broader variability, with negative values (-0.986), showed there is inconsistent experience with integrating business into R&D processes. Therefore, collaboration between academia and industry is affected by barrier related to hierarchy or organization structure.

Next, in Figure 3, rain clouds are in the categories of analyzed factors.

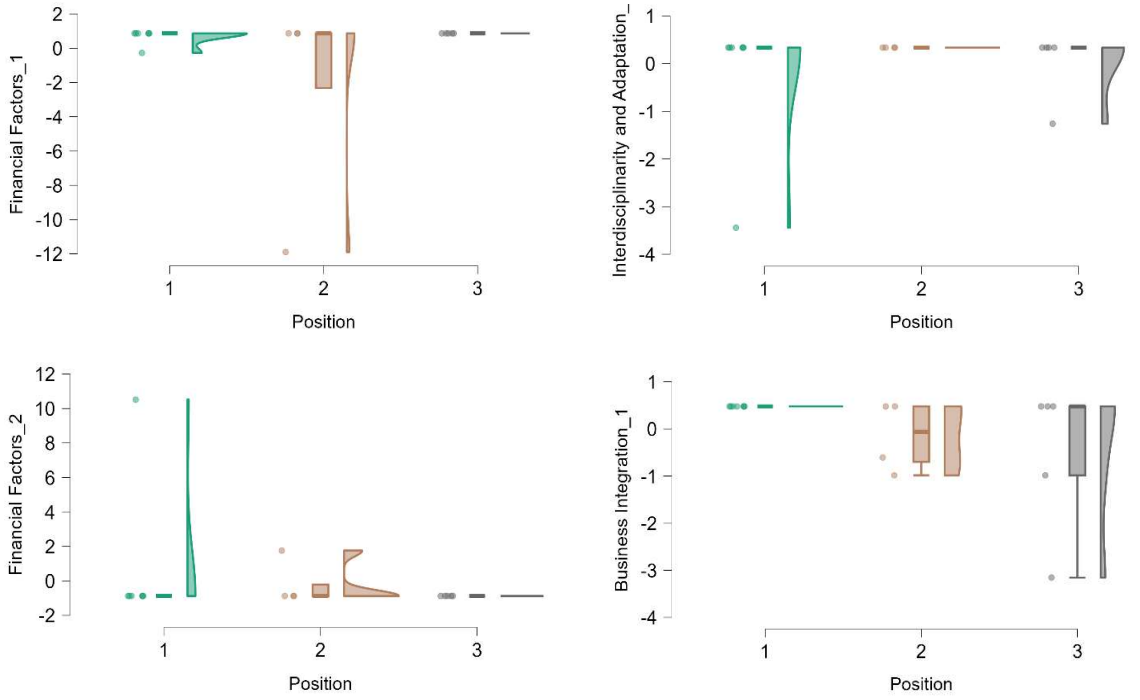

Figure 3. Distribution of expert assessments on key R&D factors

Note: complied based on JASP calculations

The analysis of the raincloud plots revealed differences in perceptions of key factors across the identified academic positions. The factor Infrastructure and Support showed that lecturers and professors consistently expressed negative evaluations, reflecting dissatisfaction with available resources and support systems. Heads of departments demonstrated mixed perceptions, with some outliers indicating localized adequacy or partial satisfaction.

For Financial Factors 1, heads of departments exhibited significant variability, with extreme negative values highlighting pronounced challenges in financial flexibility and funding support. Lecturers presented relatively stable but predominantly negative perceptions, while professors maintained a neutral to slightly negative outlook, suggesting a more tempered view. Meanwhile, Financial Factors 2 indicated that lecturers held a concentrated but predominantly positive evaluation, reflecting confidence in certain funding sources such as internal and international channels. Heads of departments expressed moderate concerns, whereas professors remained neutral, potentially reflecting limited engagement with or reliance on these financial mechanisms.

Regarding interdisciplinarity and adaptation, lecturers reported concentrated negative perceptions, indicating challenges in interdisciplinary research and adaptation of foreign models. Heads of laboratories and departments displayed neutral tendencies, while professors showed slightly more positive alignment, which may have reflected greater opportunities for collaboration or adaptability at senior levels. Lastly, Business Integration highlighted broad challenges for professors, who exhibited a wider range of negative perceptions regarding business collaboration and commercialization processes. Heads of departments demonstrated moderate variability, while lecturers remained neutral to slightly negative, indicating limited involvement or awareness of these processes.

Overall, the analysis suggested that lecturers consistently faced significant challenges across most factors, particularly in infrastructure, support, and interdisciplinary engagement. Heads of departments experienced pronounced variability, reflecting differing local conditions or responsibilities. Professors and deans demonstrated relatively neutral trends, although challenges persisted in adapting research outcomes to business contexts. These results underscored the need for differentiated strategies based on academic position to address financial mechanisms, infrastructure, and collaborative opportunities.

Table 3. Integrated factors influencing R&D support in universities

Category	Factor	Key issues	Impact/Dependency
Financial Factors	State R&D funding; private R&D funding; international R&D funding.	Limited flexibility in expenditures; bureaucratic delays; low access to external funds.	Funding availability influences infrastructure and research quality.
Infrastructure Support	Material-technical base; scientific infrastructure.	Outdated equipment; insufficient resources for modernization.	Strongly dependent on internal and external funding sources.
Human Resource Support	Personnel retention; young scientists' opportunities; motivation to publish.	Lack of career stability; low motivation for publications.	Affected by financial resources and academic workload.
Barriers and Constraints	Bureaucratic risks; publication requirements.	Administrative inefficiencies; pressure for publications;	Limits overall research productivity and financial management.
Business Integration	Role of business partners; R&D commercialization; successful collaboration.	Limited market implementation; focus on short-term applied research.	Depends on partnerships and funding flexibility.
Flexibility in Expenditures	Internal funding; spending flexibility.	Fixed budget structures; delays in resource allocation.	Influences infrastructure development and research progress.

Note: compiled based on calculations

The primary factors influencing R&D support in universities were identified. The limited availability of international funding and bureaucratic barriers to the attraction of external resources, which in turn restricts opportunities for the modernization of infrastructure and the provision of large-scale research projects. At the same time, weak engagement of business partners and a focus on short-term goals limit the potential for commercialization, blocking the market implementation and long-term adoption of research innovations.

Additionally, strict budget structures and delays in resource allocation have a negative impact on the provision of timely resources, slowing down both the development of scientific infrastructure and the realization of promising initiatives. Another issue is insufficient support for young scientists, and the absence of retention programs exacerbates staff turnover, which results in the loss of continuity and valuable expertise within research teams or educational institutions on the whole.

It is also worth noting that inflexible financial policies and administrative inefficiencies amplify financial constraints, impeding the equitable distribution of resources and increasing the burden on research groups; simultaneously, the pressure to meet publication requirements shifts the focus from the quality of research to quantitative outputs, undermining scientific productivity and the innovation potential of universities.

In Figure 4, correlation analysis for proposition checking is provided.

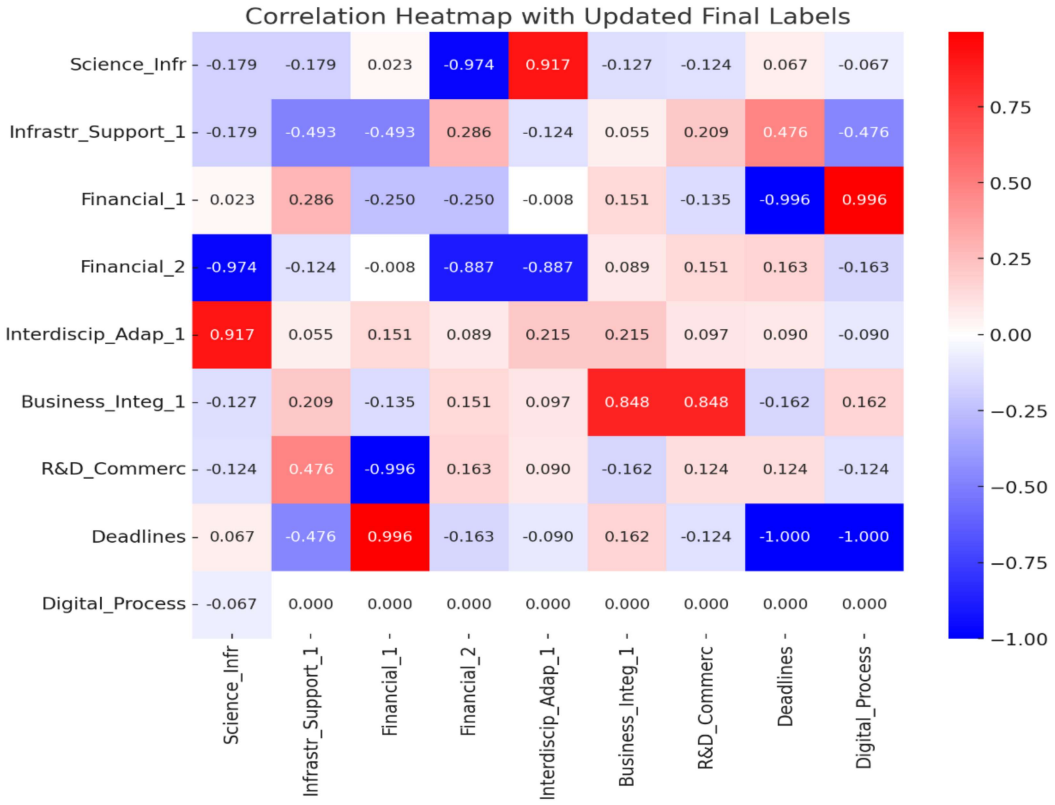

Figure 4. Correlation matrix of expert assessments on R&D support factors

Note: compiled based on Python

Some propositions needed to be confirmed, and some showed an insignificant relationship.

The following relationships were not confirmed as reflected no or very weak correlation. First, the Connection between scientific infrastructure and business integration showed a weak correlation between Scientific Infrastructure and Business Integration (-0.127) or a negligible influence of infrastructure on business interactions. Secondly, the correlation between the Role of interdisciplinarity and R&D_Commercialization (0.097) is very low as well. Thirdly, Financial constraints and business

integration showed no dependency due to a weak correlation (0.089, Financial_Factors_2 and Business Integration).

Apart from a weak or no relationship, the Impact of digitalization on deadlines showed a strong but negative relationship and adverse effects or systemic issues, which also was not aligned with the provided proposition.

The following correlation matrix results supported the provided propositions and showed a positive effect. Scientific infrastructure was positively correlated with interdisciplinarity (0.917), confirming the influence of advanced infrastructure on fostering interdisciplinary research. Next, business integration and R&D commercialization showed a high positive correlation (0.848), indicating that successful collaboration with business partners contributes to the implementation of research results.

The following group of relationships supported the provided propositions but showed negative effects. First, Financial constraints (Financial Factors_2) had a strong negative impact on scientific infrastructure (-0.974), marking the dependence of infrastructure modernization on international funding.

Secondly, deadlines and financial flexibility (Financial Factors_1) exhibited a strong negative relationship (-0.996), in that financial inflexibility and delays predominantly have considerable impact on projects' timelines. Thirdly, Process digitalization is inversely correlated with financial constraints (0.996), highlighting the reliance of digital solutions on financial flexibility. High financial constraints, such as lack of funds or financial flexibility, negatively impact process digitalization at higher education institutions, and limited funding stops them from implementing or expanding digital solutions. Conversely, greater financial flexibility as less financial constraint contributes to adopting process digitalization, such as automation, improved workflows, and digital tools. Thus, financial flexibility is a critical enabler of digital solutions, and without it, the digitalization process becomes significantly hindered.

Thus, the matrix confirms that financial constraints, spending inflexibility, and insufficient business collaboration hinder infrastructure development, digitalization, and commercialization of R&D, amplifying systemic barriers.

CONCLUSIONS

The purpose of the current research was to conduct a comprehensive analysis of the key factors affecting R&D support in Kazakhstan and to identify the main financial, infrastructural, and institutional challenges that hinder the efficient use of R&D resources. The obtained results revealed key economic constraints that hinder the effectiveness and sustainability of research activities.

Financial rigidity, limited budgetary flexibility, and weak integration with business partners have been identified as critical barriers to the long-term economic impact of R&D. Inflexible budget policies delay the modernization of research infrastructure and disrupt timely project implementation, thereby reducing the competitiveness and scalability of research outputs. Thus, the cause for low technological innovations and cost-saving digital technologies is limited financial adaptability and the inability to reallocate resources. As a result, operational inefficiencies increase, leading to a wider gap in resource sufficiency. Thus, the reason for the low level of innovation and development of digital technologies is limited financial support and the inability to redistribute resources.

Weak support for young scientists and outdated scientific infrastructure exacerbate the crisis in the academic environment. Insufficient attention to the career growth and motivation of young researchers leads to the outflow of specialists and the loss of intellectual potential. At the same time, outdated equipment and lack of resources to update the technical base limit the possibilities for conducting high-quality research and achieving scientific results. This situation is exacerbated by the low level of funding for introducing modern tools, hindering the effective management of scientific processes and further research development.

Additionally, universities' low capacity in attracting business partners and engaging in commercial activities was revealed due to weak linkages with industry. The underutilization of university-business collaboration equals missed opportunities to enhance the commercialization potential of R&D outputs due to the low capacity for co-financing arrangements. Ultimately, there are few opportunities for universities to diversify funding streams. This, in turn, increases the reliance on internal and state funding, which is often subject to administrative delays and restrictive financial controls affecting the long-term sustainability of research activities.

In order to overcome the identified problems and create a research ecosystem in Kazakhstan, a holistic policy must be implemented to support research activities. Diversification of funding sources is crucial to overcoming existing challenges, and it is essential to enhance financial flexibility for the reallocation of resources to meet changing project demands and support infrastructure modernization.

Universities should strengthen business partnerships to attract private investment, co-finance R&D projects, and accelerate the commercialization of research results. This requires the introduction of clear career paths and mentoring programs to retain promising personnel in the academic environment, as well as the priority reinvention of scientific infrastructure, including the creation of modern research centers and the introduction of digital platforms and cloud technologies for managing research, improving access to international databases, and increasing digital literacy among researchers.

Future research should focus on studying successful international scientific support models and adapting them to the Kazakh context. Additionally, more in-depth research on effective financial models, such as flexible budgeting mechanisms and co-funding, is needed for the sustainable development of the research ecosystem.

AUTHOR CONTRIBUTIONS

Conceptualization and theory: AT; research design: AT; data collection: AT; analysis and interpretation: AT; writing draft preparation: AT; supervision: KB; correc-tion of article: AT; proofread and final approval of arti-cle: AT. All authors have read and agreed to the published version of the manuscript.

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