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ASSESSMENT AND IMPROVEMENT OF THE ELEMENTS OF THE SCIENTIFIC INFRASTRUCTURE OF THE REPUBLIC OF KAZAKHSTAN

This study presents a comprehensive investigation into the nexus between research and development (R&D) services at universities, government funding, and the national R&D expenditure in Kazakhstan. Utilizing quantitative data for the period from 2014 to 2021, sourced from the Bureau of National Statistics of Kazakhstan and World Bank Open Data, the research uncovers critical trends and correlations that affect Kazakhstan's scientific landscape. Our study discovered a declining trend in the allocation of university funds towards R&D services from 2018 onwards, with a notably low share of 0.23 in 2021, suggesting a potential shift in universities' priorities. Moreover, we established a strong positive correlation of approximately 0.879 between R&D expenditure (as a percentage of GDP) and the number of researchers per million inhabitants. This correlation signifies that roughly 77.1% of the variation in the number of researchers can be attributed to the fluctuation in R&D expenditure. The data also revealed that for every 1% increase in GDP allocated to R&D, there is an increase of about 2335 full-time equivalent (FTE) researchers per million inhabitants. This analysis points towards a substantial and statistically significant influence of R&D expenditure on the number of researchers in Kazakhstan. Our findings underscore the necessity of fostering a robust scientific infrastructure via targeted R&D investment to facilitate Kazakhstan's progression towards a knowledge-based economy. Additionally, these findings highlight the crucial role of universities in shaping the country's R&D landscape. The study offers valuable insights for policymakers and researchers about the interplay between university services, government funding, and national R&D expenditure, contributing to the broader discourse on scientific and economic development in Kazakhstan.

Keywords: *R&D services, government funding, national R&D expenditure, scientific infrastructure, research investment, knowledge economy, national R&D expenditure, scientific infrastructure, research productivity, innovation policy*
Кілт сөздер: *ҒЗТКЖ қызметтері, мемлекеттік қаржыландыру, ҒЗТКЖ ұлттық шығындары, ғылыми инфрақұрылым, зерттеулерге инвестициялар, білім экономикасы, ҒЗТКЖ ұлттық шығындары, ғылыми инфрақұрылым, зерттеулердің өнімділігі, инновациялық саясат*
Ключевые слова: *услуги в области НИОКР, государственное финансирование, национальные расходы на НИОКР, научная инфраструктура, инвестиции в исследования, экономика знаний, национальные расходы на НИОКР, научная инфраструктура, продуктивность исследований, инновационная политика*

JEL classification: H52, H54, I22, I23, O30

Introduction. As we navigate the era of global digital transformation, the significance of Research and Development (R&D) comes to the fore. R&D, accounting for an estimated 2.6% of the global GDP, serves as a powerful engine of innovation, driving scientific progress, technological breakthroughs, and underpinning economic prosperity.

Situated at the crossroads of Central Asia, Kazakhstan, an emerging economy with a GDP of $220.5 billion, has been experiencing economic diversification for the past two decades. Despite the nation's abundant natural resources, particularly oil, which makes up 60% of its total exports, the government has recognized the importance of transitioning to a knowledge-based economy to secure sustainable economic growth. To successfully navigate this transition, a robust scientific infrastructure bolstered by dynamic research and development (R&D) activities, which currently represent 0.18% of the country's GDP, becomes paramount.

Universities play a central role in this transformation process. In Kazakhstan, with over 130 higher education institutions, the pressure for universities to adapt to these roles is escalating. Therefore, a meticulous exploration of their involvement in R&D services is warranted.

The role of government funding, which contributes to approximately 70% of the total R&D expenditure in Kazakhstan, is another essential facet to consider. Its adequacy and distribution can significantly impact a nation's scientific infrastructure and its capacity for innovation.

This study also investigates national R&D expenditure in Kazakhstan, and its implications for the nation's scientific landscape. Specifically, it examines the influence of R&D expenditure on the number of researchers per million inhabitants, which was around 630 in 2021, providing a more comprehensive understanding of the role of universities, government funding, and R&D expenditure in shaping Kazakhstan's scientific trajectory.

The objective of this study is twofold. Firstly, it aims to uncover the trends in R&D services provided by universities in Kazakhstan from 2014 to 2021. Secondly, it examines the relationship between R&D expenditure and the number of researchers per million inhabitants using correlation and regression analyses.

Literature review. *Universities and R&D Services.* Universities are critical institutions within the knowledge economy, directly contributing to the creation, dissemination, and application of knowledge. In the literature, this multifaceted role of universities has been termed as the «Triple Helix» model, which posits that universities, industry, and government are intertwined in a complex network that propels economic and social development [1]. This model underscores the importance of collaboration and knowledge exchange among these three sectors, particularly in fostering R&D services.

Traditionally, universities have been known for their core functions of teaching and research. However, in recent decades, their role has expanded to encompass third-stream activities such as innovation, technology transfer, and the commercialization of knowledge [2,3]. This evolution of universities as contributors to R&D has been attributed to the increasingly knowledge-driven nature of our global economy [4]. Universities, with their vast intellectual resources and research capabilities, are well-positioned to drive the creation of new knowledge, promote innovation, and contribute to technological advancements [5].

A significant area of Interest wit"In t'e academic literature is the increasing role of universities in research and development activities. Driven by the "third mission" of universities, which extends beyond their traditional teaching and research roles, they are increasingly expected to contribute to regional and national economic development [6].

Government Funding and Research Activities. The importance of government funding in promoting R&D activities is another prominent theme in the literature. It is generally agreed that government funding is a critical component of the research ecosystem [7].

A recent comprehensive study by Hicks [8] analyzed the relationship between government funding and research output across different countries. Hicks found a positive correlation between public funding and the number of research publications, suggesting the crucial role of government funding in promoting research activities. Government funding can have direct and indirect effects on research activities, influencing the direction and volume of research, and often acting as a catalyst for additional funding from private sources [9].

Azoulay, Graff Zivin, and Manso [10] conducted a study focusing on how funding structures might influence the nature of research. They found that flexible, longer-term funding could encourage more innovative and high-risk research, implying the importance of not only the amount but also the structure of government funding. In the context of Kazakhstan, a report by OECD [11] on Kazakhstan's innovation policy suggested that government funding had been a key driver of research activities in the country. However, it also recommended that Kazakhstan diversify its funding sources for research to ensure sustainable and diversified research activity.

National R&D Expenditure and Scientific Infrastructure. The role of national research and development (R&D) expenditure in strengthening the scientific infrastructure has been a focal point in the economic literature. Salter and Martin [12] asserted that national R&D expenditure significantly influences a country's scientific and technological capabilities. This view was supported by a study by Khan and Luintel [13], who found a positive relationship between R&D expenditure and the number of researchers in a given country. They suggested that countries that invest more in R&D are likely to foster a richer scientific and research environment, which in turn, attracts and develops more research professionals. A study by Guellec and van Pottelsberghe de la Potterie [14] involving 16 OECD countries found that increases in national R&D expenditure as a percentage of GDP lead to increases in patent applications, serving as a proxy for scientific innovation. The study thereby suggested that enhanced R&D investments contribute to scientific infrastructure by stimulating innovative activities.

In contrast, a study by Furman, Porter, and Stern [15] suggested that it's not just the level of R&D expenditure that matters but also the effectiveness of how these resources are utilized. The authors argued for more effective management and allocation of R&D expenditure to maximize its impact on scientific infrastructure.

The main part. *Methodology.* This study employed a purely quantitative research design to examine the role of universities in improving research and development services within Kazakhstan and to ascertain the influence of government funding and national R&D expenditure on the country's scientific infrastructure and research capabilities.

Data Collection: Data for this study was obtained from two principal sources. The first source was the Bureau of National Statistics of Kazakhstan (n.d.), which provided detailed annual data from 2014 to 2021 about the expenditure on research and development services and overall services at universities in Kazakhstan. The second source was the World Bank Open Data (n.d.), an extensive database that provided national-level data related to the Research and Development (R&D) expenditure as a percentage of the Gross Domestic Product (GDP), and the number of researchers per million inhabitants. The data from these sources was carefully collated, ensuring that it adhered to the timeframe under study and the specific parameters required for our investigation.

Data Analysis: For the analysis of the data, we used Python, a popular programming language known for its robust data analysis capabilities. The analysis was done in two stages. In the first stage, we analysed the trends in research and development services offered by universities in Kazakhstan, focusing on how these services have evolved over the years. This involved identifying patterns and interpreting the underlying factors affecting these trends. In the second stage, we conducted a correlation analysis to examine the relationship between R&D expenditure as a percentage of GDP and the number of researchers per million inhabitants. The result was a correlation coefficient, a numerical measure of the degree of relationship between these two variables. To further enhance our understanding of this relationship, a regression analysis was conducted. This was to ascertain the extent to which the variation in the number of researchers per million inhabitants can be explained by changes in the R&D expenditure as a percentage of GDP. Throughout these analysis stages, we ensured the application of appropriate statistical tests to validate the results and interpretations. It is noteworthy to mention that this study only incorporated quantitative data and analysis techniques. No qualitative data or mixed methods were employed at any stage of the research. With a rigorous data collection and analysis approach, this study seeks to provide valuable insights into the interconnections between university research services, governmental funding, national R&D expenditure, and their collective impact on the scientific progress and intellectual capacity of Kazakhstan.

Findings and Analysis. Our research began with an examination of the role of universities in improving research and development services within Kazakhstan. .

Figure 1 clearly shows that the increasing trend in general university services combined with the decline in research and development services may indicate a shift in university priorities.

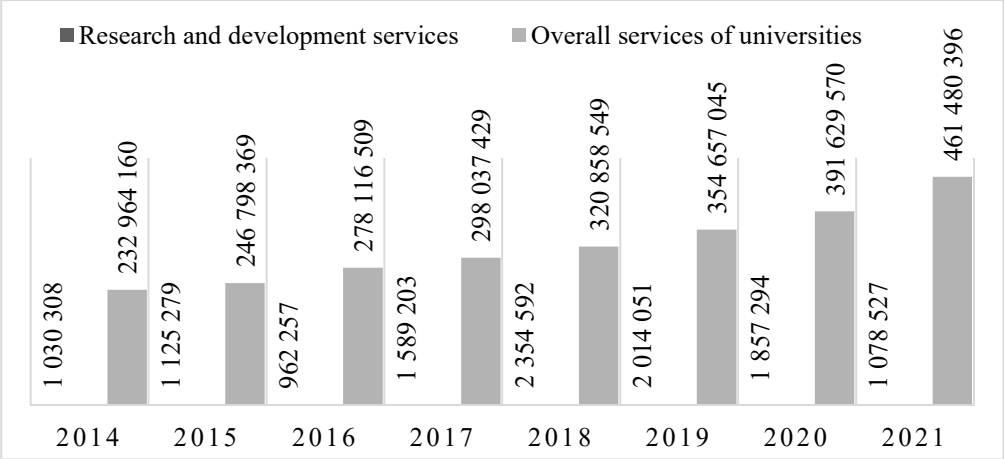

Figure 1. **R&D and University Services Expenditure in Kazakhstan***

** Compiled by the authors*

We wanted to examine how this spending affects the improvement of the country's scientific infrastructure, particularly through its impact on the number of researchers per million inhabitants. This research provides crucial insight into how financial investment in research and development can directly influence the landscape of scientific research, human capital, and overall progress in Kazakhstan.

We have examined the relationship between research and development (R&D) expenditure as a percentage of gross domestic product (GDP) and the number of researchers per million inhabitants. The tool used to quantify this relationship was correlation analysis, and the results provided important insights. The correlation coefficient yielded a value of about 0.879. This value is very close to 1, indicating a high positive correlation between the two variables: R&D expenditure (% of GDP) and the number of researchers per million inhabitants. This indicates that as the percentage of GDP spent on R&D increases, the number of researchers per million inhabitants increases accordingly. The strength of the correlation, which is close to 0.879, means that about 77.1% (0.879 squared to calculate the coefficient of determination) of the variation in the number of researchers per million inhabitants can be explained by the variation in R&D expenditure as a percentage of GDP. This is a significant proportion and suggests a significant impact of R&D expenditure on the number of researchers. It suggests that increasing investment in R&D could potentially cause an upswing in the number of researchers in a given population. Moreover, this high correlation underscores the importance of a nation's investment in R&D. Countries that spend a larger share of their GDP on R&D are likely to have more researchers per million inhabitants. This means that the more funding allocated to R & D, the more scientific research.

The result of the analysis is not equivalent to a causal relationship, although it shows a clear correlation. For example, a strong positive correlation suggests that there is a positive correlation, but it does not prove that R & D spending increases the number of researchers in the population. Because there may be other factors that influence this, as a result of the impact as a set. Or, perhaps, countries with a large number of scientific researchers tend to invest in R & D.

However, the results of this study may be the starting point for future research. It can also create new perspectives on how investing in R & D will affect the generation of talent in this area. As a continuation of correlation analysis, we decided to make regression analysis.

Table 1

Results of regression analysis*

Name	Value
Dependent Variable	Researchers per million inhabitants (FTE)
Independent Variable	Research and development expenditure (% of GDP)
R-squared	0.7721963531486121
Adj. R-squared	0.7396529750269853
F-statistic	23.728217466011795
Prob (F-statistic)	0.0018118446496248803
Research and development expenditure	2334.8656182094896
Standard Error	479.3241746035236
t-value	4.871161818910532
p-value	0.0018118446496248877

** Compiled by the authors*

The slight decrease in the adjusted R-squared value compared to the R-squared value indicates that most of the explanatory power of the model is not due to overfitting, so the explanatory power of the model is substantial.

The F-statistic is 23.73, and the probability of this F-statistic (Prob(F-statistic)) is approximately 0.0018, which is significantly less than 0.05. This signifies that our regression model is statistically significant at the 5% level. This implies that there is a statistically significant relationship between R&D expenditure (% of GDP) and the number of researchers per million inhabitants.

Based on the results of the regression analysis, the econometric model for the relationship between «Research and development expenditure (% of GDP)» (X) and «Researchers per million inhabitants» (Y) can be written as follows:

$$\mathbf{Y = 370.0053 + 2334.8656^{*}\ X}$$

In this model:

Y represents the estimated value of «Researchers per million inhabitants».

X represents the value of «Research and development expenditure (% of GDP)».

The constant term is 370.0053, which represents the estimated value of Y when X is zero.

The coefficient for the R&D expenditure is 2334.87, which suggests that for every 1% increase in GDP allocated to R&D, there is an increase of about 2335 full-time equivalent (FTE) researchers per million inhabitants. This positive relationship, combined with a low p-value of approximately 0.0018 for the t-statistic (significantly less than 0.05), indicates that the effect of R&D expenditure on the number of researchers per million inhabitants is statistically significant.

Conclusion. With a focus on the role of universities, the effects of government funding, and the impact of R&D expenditure as a percentage of the Gross Domestic Product (GDP), this study set out to explore the intricate and interconnected landscape of Research and Development (R&D) in Kazakhstan. Our quantitative analysis, which included information from the World Bank Open Data and Kazakhstan's Bureau of National Statistics, provides a thorough summary of these dynamics from 2014 through 2021.

Our findings revealed a decreasing trend in the allocation of university funds towards R&D services from 2018 onwards, which may have far-reaching implications on the quality of education, the international ranking of universities, and the overall scientific progress of the country. While universities are expected to provide a broad range of services, a decrease in the emphasis on research could impact their standing as the central hubs for knowledge creation and technological innovation.

When we turned our attention to national R&D expenditure, our study indicated a high positive correlation between the R&D expenditure as a percentage of GDP and the number of researchers per million inhabitants. The correlation coefficient of 0.879 suggests that increased R&D expenditure is associated with an increase in the number of researchers, which is consistent with the general belief that higher investment in R&D fosters a conducive environment for scientific research.

Our regression analysis further corroborated this relationship, with an R-squared value of 0.772 indicating that about 77.2% of the variation in the number of researchers per million inhabitants could be explained by the variation in R&D expenditure as a percentage of GDP. The results provided strong evidence for the significant impact of R&D expenditure on the number of researchers, pointing to the importance of strategic investment in R&D to boost the nation’s scientific manpower.

However, as with all research, this study has its limitations. Correlation does not imply causation, and the presence of other unobserved variables might be influencing the results. While our study provides a valuable starting point, future research should consider a more extensive set of variables and use more advanced statistical models to gain a more comprehensive understanding of the factors influencing R&D and its impact on the scientific landscape in Kazakhstan.

The findings of this research bear important implications for policymakers in Kazakhstan. The decreasing emphasis on R&D within universities and the significant impact of R&D expenditure on the number of researchers underscore the need for targeted policies that promote investment in scientific research, encourage universities to prioritize R&D, and create an enabling environment for knowledge creation and innovation.

As Kazakhstan navigates its way towards becoming a knowledge-based economy, the findings of this research will hopefully contribute to the formulation of more informed and effective strategies for strengthening the nation’s scientific and technological prowess.

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ҚАЗАҚСТАН РЕСПУБЛИКАСЫНЫҢ ҒЫЛЫМИ ИНФРАҚҰРЫЛЫМЫНЫҢ ЭЛЕМЕНТТЕРІН БАҒАЛАУ ЖӘНЕ ЖЕТІЛДІРУ

Аңдатпа

Бұл зерттеу университеттердегі зерттеулер мен әзірлемелер (R&D) саласындағы қызметтер, Қазақстандағы ҒЗТКЖ-ға мемлекеттік қаржыландыру және Ұлттық шығыстар арасындағы өзара байланысты жан-жақты зерттеу болып табылады. Қазақстанның Ұлттық статистика және Дүниежүзілік Банктің ашық деректер бюросынан алынған 2014 жылдан 2021 жылға дейінгі кезеңдегі сандық деректерді пайдалана отырып, зерттеу Қазақстанның ғылыми ландшафтына әсер ететін аса маңызды үрдістер мен корреляцияларды ашады. Біздің зерттеуіміз 2018 жылдан бастап ғылыми-зерттеу қызметтеріне университет қаражатының бөлінуінің төмендеу тенденциясын анықтады, 2021 жылы 0,23 үлесі айтарлықтай төмен, бұл университет басымдықтарының ықтимал өзгеруін көрсетеді. Сонымен қатар, біз ҒЗТКЖ шығындары (ЖІӨ пайызымен) мен миллион тұрғынға шаққандағы зерттеушілер саны арасында шамамен 0,879-да күшті оң корреляция орнаттық. Бұл корреляция зерттеушілер санындағы өзгерістердің шамамен 77,1% -. ҒЗТКЖ шығындарының ауытқуымен түсіндіруге болатындығын білдіреді. Деректер сонымен қатар ҒЗТКЖ-ға бөлінетін ЖІӨ-нің әрбір 1% өсімі миллион тұрғынға шаққанда шамамен 2335 толық уақытты зерттеушіге (FTE) өсетінін көрсетті. Бұл талдау ҒЗТКЖ шығыстарының Қазақстандағы зерттеушілер санына елеулі және статистикалық маңызды әсерін көрсетеді. Біздің қорытындыларымыз Қазақстанның білімге негізделген экономикаға ілгерілеуіне жәрдемдесу үшін ҒЗТКЖ-ға нысаналы инвестициялар арқылы сенімді ғылыми инфрақұрылым құру қажеттігін көрсетеді. Сонымен қатар, бұл нәтижелер университеттердің елдің ғылыми-зерттеу ландшафтын қалыптастырудағы шешуші рөлін көрсетеді. Зерттеу саясаткерлер мен зерттеушілерге Қазақстанның ғылыми және экономикалық даму мәселелерін кеңінен талқылауға ықпал ете отырып, университеттік қызметтер, мемлекеттік қаржыландыру және Ұлттық ҒЗТКЖ шығындары арасындағы байланыс туралы құнды ақпарат береді.

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ОЦЕНКА И СОВЕРШЕНСТВОВАНИЕ ЭЛЕМЕНТОВ НАУЧНОЙ ИНФРАСТРУКТУРЫ РЕСПУБЛИКИ КАЗАХСТАН

Аннотация

Данное исследование представляет собой всестороннее исследование взаимосвязи между услугами в области исследований и разработок (R&D) в университетах, государственным финансированием и национальными расходами на НИОКР в Казахстане. Используя количественные данные за период с 2014 по 2021 год, полученные из Бюро национальной статистики Казахстана и Открытых данных Всемирного банка, исследование раскрывает важнейшие тенденции и корреляции, которые влияют на научный ландшафт Казахстана. Наше исследование выявило тенденцию к снижению выделения университетских средств на научно-исследовательские услуги с 2018 года и далее, с заметно низкой долей в 0,23 в 2021 году, что свидетельствует о потенциальном изменении приоритетов университетов. Более того, мы установили сильную положительную корреляцию примерно в 0,879 между расходами на НИОКР (в процентах от ВВП) и числом исследователей на миллион жителей. Эта корреляция означает, что примерно 77,1% изменений в численности исследователей можно объяснить колебаниями расходов на НИОКР. Данные также показали, что на каждый 1%-ный прирост ВВП, выделяемый на НИОКР, приходится увеличение примерно на 2335 исследователей, занятых полный рабочий день (FTE), на миллион жителей. Этот анализ указывает на существенное и статистически значимое влияние расходов на НИОКР на численность исследователей в Казахстане. Наши выводы подчеркивают необходимость создания надежной научной инфраструктуры посредством целевых инвестиций в НИОКР для содействия продвижению Казахстана к экономике, основанной на знаниях. Кроме того, эти результаты подчеркивают решающую роль университетов в формировании научно-исследовательского ландшафта страны. Исследование дает ценную информацию политикам и исследователям о взаимосвязи между университетскими услугами, государственным финансированием и национальными расходами на НИОКР, способствуя более широкому обсуждению вопросов научного и экономического развития Казахстана.