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Article

The role of non-parametric and parametric methods in benchmarking research performance

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Abstract: This study examines the effectiveness of Kazakhstan's grant funding system in supporting research institutions and universities, focusing on the relationship between funding levels, expert evaluations, and research outputs. We analyzed 317 projects awarded grants in 2021, using parametric methods to assess publication outcomes in Scopus and Web of Science databases. Descriptive statistics for 1606 grants awarded between 2021 and 2023 provide additional insights into the broader funding landscape. The results highlight key correlations between funding, evaluation scores, and journal publication percentiles, with a notable negative correlation observed between international and national expert evaluations in specific scientific fields. A productivity analysis at the organizational level was conducted using non-parametric methods to evaluate institutional efficiency in converting funding into research output. Data were manually collected from the National Center of Science and Technology Evaluation and supplemented with publication data from Scopus and Web of Science, using unique grant numbers and principal investigators' profiles. This comprehensive analysis contributes to the development of an analytical framework for improving research funding policies in Kazakhstan.

Keywords: grant funding system; research performance analysis; Kazakhstan universities; parametric and non-parametric methods; research funding policies evaluation

1. Introduction and literature review

In Kazakhstan, a country with a rapidly evolving educational and research landscape, understanding the effectiveness of grant funding systems is essential for developing policies that support scientific productivity and international research visibility. Although research funding assessments have been widely conducted in developed countries, there is a gap in studies focusing on emerging research environments like Kazakhstan, where data infrastructure and research output standards are still evolving. This study addresses this gap by analyzing Kazakhstan's grant funding system's impact on research productivity through a combined use of both parametric and non-parametric methods.

Aligned with Kazakhstan's funding requirements, this study focuses strictly on specific variables outlined in grant documents, such as evaluation grades, funding levels, and publication percentiles. The policy documents clearly establish a hierarchy: projects with publications in higher percentiles are required to meet fewer publication or outcome criteria. Consequently, this study deliberately prioritizes these metrics as mandated by the grant criteria, intentionally setting aside other factors typically included in performance assessments, such as the size of the research team, prior publication history, or access to research infrastructure. These factors are already evaluated within the expert review process and may correlate with the primary metrics.

By adhering to the grant criteria, we provide insights directly relevant to policy and funding frameworks, with practical implications for refining grant evaluation criteria and resource allocation strategies. This study's findings aim to support policymakers in enhancing the productivity and impact of funded research projects in Kazakhstan and offer insights that may extend to other countries with developing research infrastructures.

Scholars have long recognized the role of governments, through various institutional frameworks, in facilitating the transformation of scientific knowledge into innovations that enhance societal welfare (Lescrauwaet et al., 2022; Shaw, 2023). A significant instrument frequently employed to fund research initiatives is the grant system. A foundational element of modern funding allocation is the evaluation process, which often relies on peer review. Widely regarded as the gold standard, peer review is seen as an effective mechanism for selecting research projects based on quality, originality, and potential impact (Pearson, 2023; Roumbanis, 2019). Independent assessment by impartial reviewers is essential for upholding scientific integrity, evaluating the relevance of the research, and conducting cost-benefit analyses. Given its perceived efficiency and widespread credibility, peer review is often viewed as the most reliable method for assessing research proposals. However, since its adoption as the primary method for determining the allocation of resources, concerns have emerged regarding its effectiveness. Is peer review truly the best system for selecting the most innovative researchers and ideas? Can reviewers remain fully objective when evaluating the work of their peers? As the scientific landscape grows and the demand for peer reviews increases, the workload for reviewers becomes more demanding and time-intensive, potentially compromising their ability to accurately assess project quality. This could hinder the system's ability to filter out lower-quality proposals and ensure that funding is awarded to the most deserving projects.

For instance, studies have uncovered various biases in the peer review process that challenge its fairness. Country-specific data has shown evidence of the "Matthew effect", where successful researchers are more likely to continue succeeding, thus reinforcing their prominence (Bol et al., 2018; Sun et al., 2023). Similarly, gender bias has been identified, with some research suggesting that male applicants may receive preferential treatment over their female counterparts in the peer review system (Van Der Lee et al., 2015). Ethnic bias is another concern, as research by Ginther et al. (2011) highlights that, despite the scientific approach and significance score being key predictors of funding success, ethnicity still appears to play a role in the outcomes. Furthermore, Materia et al. (2015) demonstrated that the composition of the review team, in studies on agricultural research projects, could influence funding decisions. In extreme cases, these biases can affect funding outcomes to the extent that the reviewer's identity plays a more significant role than the quality of the proposed research itself.

The grant peer review process can entail significant costs, particularly in terms of time and effort, which may outweigh its potential benefits. For instance, research using contest models suggests that the resources spent by researchers in preparing proposals could be nearly equivalent to the total scientific value generated by the funded research, especially when only a limited number of proposals are selected for funding (Gross and Bergstrom, 2019). Another study found that the collective effort was equivalent to approximately four centuries of work, yet yielded no immediate benefits to the researchers and resulted in lost research time. Moreover, the process of preparing funding applications is often stressful, incurs significant opportunity costs, and detracts from personal obligations such as family commitments (Herbert et al., 2014).

The findings related to biases and potential limitations of the grant review system are not definitive in assessing the efficiency and fairness of peer review, primarily because these studies are based on relatively small sample sizes compared to the entire grant system. However, they do highlight the need for further examination of the current system, as broader validation of these findings could impact outcomes and limit opportunities for participation and representation in scientific research (Demarest et al., 2014). Various alternatives have been proposed, such as the suggestion that funding priority should be given to projects where evaluators show the greatest disagreement, rather than consensus on merit and impact (Linton, 2016). Despite these ideas, systematic evidence on the effectiveness of alternative proposal evaluation methods remains scarce.

A substantial body of research has been dedicated to assessing research productivity through the lens of scientometric data, focusing on the ramifications of competitive research funding distributed by various agencies as well as the broader implications of funding environments across different countries. Langfeldt, Bloch and Sivertsen (2015) conducted a comparative analysis of Danish and Norwegian research grant recipients against applicants who were denied funding. Their findings indicated that the publication output of those who received grants significantly exceeded that of the non-recipients, particularly when comparing the periods before and after the receipt of funding. Although grantees also tended to produce publications that garnered higher citation counts, the differential in mean normalized citation scores between grantees and non-recipients was not statistically significant. Neufeld (2016) adopted a similar methodology to evaluate disparities in research performance between funded and non-funded applicants of a German DFG research grant within the disciplines of biology and medicine. The study observed modest improvements in research output attributable to funding in biology, whereas no significant effect was detected in medicine. Additionally, the Academy of Finland, which serves as Finland's principal public research funding agency, utilizes a bibliometric indicator based on the Web of Science to gauge the effectiveness of its research funding. This approach is complemented by an alternative methodology that benchmarks the research performance and scholarly communication profile of the academy research against the total output of Finnish universities across a spectrum of arts and sciences (Pölönen and Auranen, 2022). Event-specific studies, such as those examining the impact of the ongoing conflict in Ukraine on the productivity and collaboration networks of Ukrainian scholars (Damaševičius and Zailskaitė-Jakštė, 2023), further enrich the discourse. In addition to evaluating the outputs of grant funding, focused studies examine the specific effects of funding programs, like the role of Japanese public funding in nurturing emerging topics within the life sciences and medicine (Ohniwa, Takeyasu and Hibino, 2023). These studies analyze publications that incorporate emerging keywords to discern which grant categories most effectively stimulate novel research topics from the perspectives of both principal investigators and funding bodies.

In Kazakhstan, the evolution of research productivity within the Higher Education and Science (HES) sector has also been subjected to scientometric scrutiny. Suleymenov, Ponomareva and Dzhumabekov (2011) analyzed publication records from Scopus to investigate trends across seven prominent research areas, elucidating development trends for Commonwealth of Independent States member countries, including Kazakhstan. Kuzhabekova and Lee (2018) assessed the contributions of international faculty at Kazakhstani universities, revealing their pivotal role in bolstering local research capacity through global networks and the dissemination of knowledge. Another study identified a positive correlation between the growth of the HES sector and an increase in research productivity, evidenced by a significant uptick in the number and citations of literature since 2011 across almost all disciplines. However, network analyses demonstrated that research in the natural sciences was more advanced in developing topic-specific relationships and international collaborations than research in other fields (Narbaev and Amirbekova, 2021). Although there is theoretical agreement on the need for such evaluations, the debate over the application of appropriate methodologies persists. Discussions regarding the merits and drawbacks of peer-review versus bibliometric methods have been extensively articulated in the scholarly literature since the late 1990s (Abramo, D'Angelo and Di Costa, 2011; MacRoberts and MacRoberts, 1996; Pendlebury, 2009).

The extant scientometric literature reveals a notable deficiency in studies focused on evaluating scholarly literature and assessing research productivity in Kazakhstan, particularly regarding the efficacy of research funding programs and their alignment with intended requirements and publication outcomes. To address this gap, this study employs the percentiles of publications from each grant project as a primary metric. The debate around the use of quantified metrics, such as publication percentiles and impact factors, as indicators of research quality remains active. Critics suggest that these metrics fail to capture the complex, multidimensional nature of research quality adequately. However, in this specific instance, the funding agency explicitly requires or implicitly favors high-percentile publications as part of their grant criteria. For example, the grant documentation for scientific projects spanning 2021–2023 specifies that in certain fields, at least one article or review must be published in a peer-reviewed journal ranked within the first or second quartile of the Web of Science database, or achieve a CiteScore percentile of at least 65 in the Scopus database. For publications not meeting these criteria, additional requirements, such as publication in national journals, are imposed (Nazarko and Šaparauskas, 2014). Given this requirement, it is reasonable to assume that researchers who receive grant funding are motivated to publish in high-percentile journals to comply with these criteria. Consequently, for the purposes of this study, we consider the percentile of publications as a dependent variable. This choice is not an endorsement of the percentile as a definitive measure of quality but rather a reflection of the current funding environment. Our approach not only aligns with the incentives provided by funding bodies but also critically acknowledges the limitations of this metric. The implications of these limitations will be further discussed in the context of research evaluation in the limitations section.

The primary research questions guiding this study are as follows:

(1) How do funding levels affect the publication outcomes, considering both the journal percentiles and total output among research projects supported by grants? This question aims to investigate the correlation between funding levels and publication percentiles, focusing on the direct link between monetary support, percentile rankings, and the number of published articles. This approach treats the percentile as a dependent variable influenced by the funding requirement rather than as a direct measure of quality.

(2) To what extent do expert evaluations (both international and national) predict the publication outcomes across different scientific directions? This question expands to consider not only the influence of funding on publication outcomes but also the impact of expert evaluations. It includes a comparison between international and national evaluations to determine if there are significant differences in how these evaluations correlate with publication percentiles across various scientific fields. This comprehensive approach captures the dynamics of funding and evaluation within the context of discipline-specific realities.

(3) Do institutional characteristics influence the performance of research projects? This question aims to examine whether and how various institutions affect the publication outcomes of their affiliated research projects. By analyzing the average expected publication percentiles and the number of indexed publications grouped by institution, this inquiry seeks to uncover potential institutional effects, such as resources, reputation, or support structures, that might correlate with higher or lower publication results.

2. Materials and methods

This study was conducted in several key stages to evaluate the effectiveness of Kazakhstan's grant funding system on research productivity. The following outlines each stage of the research process, with a focus on the selection and purpose of both parametric and non-parametric methods:

Data Collection and Verification: Data were manually collected from the National Center of Science and Technology Evaluation and supplemented with publication data from Scopus and Web of Science databases (NCTSE, 2020). Using unique grant numbers and principal investigators' profiles, we verified each publication to ensure its connection to a specific grant, which yielded a sample of 317 projects funded in 2021.

Metric Selection: In alignment with the grant funding requirements, we prioritized specific metrics such as publication percentiles, evaluation scores, and funding levels. Other factors typically used in performance assessments, such as research team size or prior publication history, were intentionally excluded as these are already evaluated within expert reviews and may correlate with primary metrics.

Application of Parametric Methods: Initially, we employed parametric methods, specifically multiple linear regression, to explore the relationships among independent variables, including total funding, international and national evaluation scores, and the primary outcome variable of publication percentiles. The parametric model allowed us to examine correlations and estimate the potential predictive power of these variables in a controlled setting. However, due to the limited explanatory power observed in the parametric models (indicated by low *R*-squared values), we transitioned to using Pearson correlation coefficients and simple linear regressions for the first and second research questions. These simpler analyses enabled us to assess individual variable relationships more effectively and provided greater interpretability of results.

Application of Non-Parametric Methods (Data Envelopment Analysis): For the third research question, which focused on institutional efficiency, we applied an output-oriented model. DEA was selected because it does not assume a predefined functional form, allowing flexibility in evaluating the relative efficiency of research institutions. This non-parametric approach enabled us to benchmark institutional performance by comparing each organization's ability to convert funding into high-percentile publications, relative to the best-performing institutions in the sample.

Since the 2020s, the mechanism for allocating research funding in Kazakhstan has undergone significant changes, both in the frequency of calls for proposals and in the variety of grant types announced. Previously, grant calls were issued once every three years, requiring a waiting period for grant completion. However, starting in the 2020s, a broader array of grant types has been introduced. **Table 1** provides a summary of these announced grant types, including the number of awards granted, the maximum funding limits, and the total allocated funding.

Table 1. Overview of grant types and funding information (2021–2023), in USD equivalent*.

Grant type	Maximum cap per project	Number of projects funded	Total funding
Grant funding 2021–2023 (12 months)	19,373	170	2,818,792
Grant funding for young scholars 2021–2023 (36 months)	130,766	151	17,951,079
Grant funding 2021–2023 (36 months)	169,512	375	50,922,561
Program-targeted financing for scientific, scientific and technical programs for 2021–2023	Depends on the government program, typically several million dollars	129	136,949,717

* The average exchange rate for 2020 (call year) was 1 USD equal to 412.95 tenge (National Bank of Kazakhstan, a).

As shown in **Table 1**, there are four types of grants: one-year small grants, three-year grants for young scholars (in which all participants, including principal investigators, must be under forty years old), three-year grants without any age or other restrictions, and program-targeted financing, where the call for proposals consists of several pre-determined technical tasks aligned with government directives. This paper focuses on the classical grant funding without any restrictions. Our focus on grants awarded in 2021 is driven by two key reasons: first, the distribution of funding in Kazakhstan has been regularly updated, and since 2021, funding has been allocated for a three-year period based on nine scientific directions. Second, following a presidential address in 2020, the level of research funding significantly increased. For comparison purposes, and to address research questions one and three—where publication percentiles were used as a dependent variable—only grants awarded in 2021 were included in the analysis, as they have now concluded and their publications will be indexed by 2024. However, the full dataset was used for descriptive statistics, particularly in addressing the second research question. The protocols have details of the decisions to fund these projects, including the project title, principal investigator, name of the research institution, funding amounts, and both international and national expert evaluations. Descriptive statistics for projects awarded between 2021 and 2023 are shown in **Table 2**. The funding dynamics reveal significant growth in research grant funding, even accounting for the depreciation of the tenge relative to the USD, from 412.95 to 460.48. In 2021, totaling the USD equivalent of 50 million. In 2022, this amount increased by 43%, and in 2023, it rose by 87%, reaching a total of 136 million USD. Additionally, the proportion of grants distributed across the nine scientific directions remained relatively stable throughout all three years.

Table 2. Grant funding dynamics for three-year projects, in USD equivalent*.

No	Scientific direction	Grant funding 2021–2023		Grant funding 2022–2024		Grant funding 2023–2025	
		Projects	Funding	Projects	Funding	Projects	Funding
1	Geology, extraction and processing of mineral and hydrocarbon raw materials, new materials, technologies, safe products, and constructions	44	6,733,810	72	12,162,085	104	20,831,733
2	Information, communication, and space technologies	28	4,121,845	27	4,511,796	74	14,440,482
3	Research in the field of education and science	31	3,079,888	48	5,445,403	74	10,071,192
4	Research in the field of social and humanitarian sciences	79	8,986,865	88	11,420,471	150	20,060,441
5	Life sciences and health	57	8,572,926	74	12,721,314	126	25,510,240
6	Sustainable development of the agro-industrial complex and agricultural product safety	14	2,003,914	13	2,248,240	40	8,052,970
7	Energy and mechanical engineering	30	4,461,344	50	8 176 597	58	11 053 100
8	Scientific research in the field of natural sciences	72	10,255,829	68	11,106,517	96	18,431,550
9	Rational use of water resources, wildlife and flora, ecology	20	2,706,139	31	5,108,752	38	7 619 477
	Total	375	50,922,561	471	72,901,174	760	136,071,186

* The average exchange rate for call years (2020–2023) were 1 USD equal to 412.95, 426.03, 460.48 tenge respectively (National Bank of Kazakhstan, a, b, c).

The grant funding for scientific or scientific-technical projects is designed to support the execution of key national programs in the Republic of Kazakhstan. Its main objectives are to elevate the quality of research, bolster scientific and technological capabilities, and improve the competitiveness of research institutions, their teams, and individual scientists. The documentation in 2020 was developed in compliance with the Law of the Republic of Kazakhstan "On Science", the Regulation on National Scientific Councils approved by the Government of Kazakhstan, the Rules for basic, grant, and program-targeted funding of scientific and/or scientific-technical activities approved by the Government on, and the Rules for conducting state scientific and technical reviews approved on 1 August 2011 (The Law of the Republic of Kazakhstan, 2011; The Regulation on National Scientific Councils, 2011; The Rules for Basic, Grant, and Program-Targeted Funding, 2011; The Rules for the

Organization and Conduct of State Scientific and Technical Expertise, 2011). Although minor adjustments were made in subsequent years, the overall system has remained largely unchanged. The requirements for expected outcomes following the implementation of projects vary depending on the research field, with the specific requirements for fundamental research requirement at that year illustrated in **Table 3** below.

Table 3. Fundamental research publication requirements for expected outcomes by field.

Research fields	Options	Minimum Requirements
Natural Sciences	1	3 articles in Q1–Q3 Web of Science or 50th percentile Scopus, and 1 article in RLCS*
	2	2 articles in Q1–Q2 Web of Science or 65th percentile Scopus
	3	1 article in 90th percentile Journal Citation Reports or 95th percentile Scopus
Technical Sciences, Life Sciences, and Medicine	1	3 articles in Science Citation Index Expanded Web of Science or 35th percentile Scopus
	2	2 articles in Science Citation Index Expanded Web of Science or 35th percentile Scopus, 1 patent in Derwent Index, 1 article in RLCS
	3	2 articles in Q1–Q2 Web of Science or 65th percentile Scopus
	4	1 article in Q1 Web of Science or 80th percentile Scopus
Agricultural and Veterinary Sciences	1	2 articles in Science Citation Index Expanded Web of Science or 35th percentile Scopus
	2	1 article in Science Citation Index Expanded Web of Science or 35th percentile Scopus, 1 patent in Derwent Index
	3	1 article in Science Citation Index Expanded Web of Science or 35th percentile Scopus, implementation act or licensing agreement, 1 article in RLCS
	4	Q1–Q2 Web of Science or 65th percentile Scopus

Table 3. (*Continued*).

Research fields	Options	Minimum Requirements
Social Sciences, Humanities, and Arts	1	1 article in Social Science Citation Index, Arts and Humanities Citation Index, Russian Science Citation Index, or 35th percentile Scopus and 2 articles in RLCS
	2	1 article in Q1–Q2 Web of Science or 65th percentile Scopus
	3	2 articles in Arts and Humanities Citation Index Web of Science

* Recommended list of journals by committee of science.

The complexity arising from multiple options and the absence of comprehensive data on the outcomes of these projects posed significant challenges in data collection and classification. Consequently, this influenced our output selection, leading us to adopt two distinct analyses: the highest percentile rank for each project and the average percentile of all publications. To maintain consistency, we exclusively used percentile ranks from the Scopus database, as it closely aligns with Web of Science rankings; the main difference being that a substantial portion of publications are not indexed in the Web of Science database. Additionally, in the descriptive section, we had the average number of authors as an indicator of project participation, alongside the total number of articles. However, this data could not be incorporated into our analysis due to its lack of representativeness, which would have inappropriately skewed the results.

So our sample selection were based on the available data in the databases. Out of total 375 projects funded in 2021–2023 period we searched via both databases web of science and scopus and also by identifying the principal investigators profile we also opened each article on the publisher website to double the existence of acknowledgement text showing the name and unique number of the peoject. In total we were able identify 317 projects and also used percentile ranks for each journal as of 2023 on scopus database.

Initially, we employed parametric methods, specifically multiple linear regression, using all available independent variables relevant to the project call requirements, such as total funding, expert evaluations, and the size of organizations measured by the total number of research staff. The multiple regression formula applied was:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \epsilon, \quad (1)$$

While some coefficients were statistically significant, the overall explanatory power of the model was relatively low. To address this limitation, we transitioned to using Pearson correlation coefficients and simple linear regressions for the first and second research questions, which allowed for more straightforward analysis of relationships between individual variables.

For the third research question, we applied Data Envelopment Analysis (DEA), specifically an output-oriented model. This non-parametric method is suitable because it does not assume a predefined functional form, making it highly adaptable to assessing the relative efficiency of research organizations. Given the diverse nature of projects and resources across institutions, DEA provides a robust way to evaluate efficiency without the rigid assumptions of parametric methods. In our study, we use the DEA specification by Banker, Charnes, and Cooper (1984), assuming variable returns to scale (VRS). This method enables us to consider the varying sizes of institutions. According to the existing literature, universities operate with a given set of inputs and seek to optimize their outputs, which supports our decision to use an output-oriented model. While DEA distinguishes between technical and scale efficiency, this differentiation is not pertinent to our research objectives. Consequently, our analysis concentrates exclusively on overall efficiency. The output-oriented DEA model aims to maximize output Y while keeping input X constant. The basic formula for this model is:

$$\text{Maximize } \phi \text{, subject to } \sum_{j=1}^{n} \boldsymbol{\lambda_j X_j} \leq \boldsymbol{X_i}, \sum_{j=1}^{n} \boldsymbol{\lambda_j Y_j} \geq \boldsymbol{\phi Y_i} \quad (2)$$

where:

- ϕ is the efficiency score for maximizing output,
- λ_j are the weights for the *j*-th decision-making unit (DMU),
- X_j and Y_j are the inputs and outputs of the *j*-th DMU,
- X_i and Y_i represent the inputs and outputs of the *i*-th DMU being evaluated.

Non-parametric methods like DEA are particularly useful in this context because they do not require strict assumptions about the functional relationships between inputs and outputs. Given the varying scale and resources of research institutions, a non-parametric approach allows for a more flexible evaluation of relative efficiency. This is especially important for our study, where the complexity and heterogeneity of research projects make it difficult to define a parametric model with accuracy. DEA offers the advantage of measuring efficiency in a manner that reflects the actual performance of institutions relative to their peers (Agasisti and Johnes, 2009; Nazarko and Šaparauskas, 2014; Thanassoulis et al., 2011; Wolszczak-Derlacz and Parteka, 2011).

In summary, this section outlines the steps taken to examine the evolving research funding mechanisms in Kazakhstan and assess the efficiency of grant-funded projects. The study utilized a combination of parametric and non-parametric methods to analyze data from projects funded between 2021 and 2023. Data collection was extensive, involving both the Scopus and Web of Science databases, and specific project details were cross-verified by checking publications for project acknowledgments.

3. Results and discussion

3.1. Impact of funding levels on publication outcomes

The results from the initial multiple regression, presented in **Table 4**, indicate that only total funding is positively correlated with the highest percentiles and is statistically significant. However, the low *R*-squared values suggest that the overall explanatory power of the model is limited. Nonetheless, we conducted three additional simple linear regressions, and **Table 5** reveals that the coefficients are similar to those from the multiple regression. An interesting observation is that the evaluation scores from international experts and total funding were significant, with positive coefficients of 0.69 and 0.16, respectively. In contrast, the scores from national experts had a negative sign, although this was not statistically significant. This unexpected result prompted further inquiry into the role of expert evaluations. This section explains the overall correlation between each expert group and the dependent variable, leading us to extend our analysis to encompass three years of data. Instead of analyzing the link between each expert group and the dependent variable separately, we focused on the relationship between the two expert groups themselves. This approach enabled us to analyze all 1606 projects awarded between 2021 and 2023, including ongoing projects, thereby increasing our sample size.

Table 4. Multiple regression summary outputs.

Regression Statistics				
Multiple *R*	0.25			
R Square	0.06			
Adjusted *R* Square	0.05			
Standard Error	17.33			
Observations	317			
	Coefficients	Standard Error	*t* Stat	*P*-value
Intercept	50.14	11.83	4.24	0.00
INT EXP	0.29	0.35	0.82	0.41
NAT EXP	−0.53	0.50	−1.07	0.28
USD/1000	0.16	0.04	4.03	0.00

Table 5. Simple regression coefficients and significance outputs.

	Coefficients	***P*-value**
Intercept	55.68	0.00
INT EXP	0.69	0.05
Intercept	79.97	0.00
NAT EXP	−0.40	0.42
Intercept	53.33	0.00
USD/1000	0.16	0.00

3.2. Role of expert evaluations in shaping publication metrics across disciplines

As previously mentioned, according to the Rules for the Organization and Conduct of State Scientific and Technical Expertise, all grant submissions undergo an eligibility check before being forwarded to a selected pool of international experts. These experts evaluate the submissions based on multiple criteria, after which a ranked list of projects is forwarded to the National Scientific Councils for each scientific direction. Our initial objective was to identify which expert group evaluations best correlate with the most favorable outcomes. To establish preliminary expectations about the relationship between the evaluations of the two expert groups, whether they should be positively or negatively correlated, we first analyzed the evaluation criteria used by both groups. **Tables 6** and **7** provides a detailed breakdown of these criteria.

Table 6. Breakdown of evaluation criteria used by international expert groups.

No	Evaluation Criterion	Indicator descriptions	Maximum points
1	Novelty, Relevance, and Prospects of the Project	Novelty and Relevance of the Proposed Scientific and Technical Level of the Project (no more than 200 words)	3
		Importance and Relevance of the Proposed Scientific and Technical Level, and the Degree of Development of the Project for the Advancement of Science (no more than 300 words)	6
2	Quality and Feasibility of the Research Plan	Quality of the Research Plan (no more than 150 words)	3
		Quality of the Research Methodology (no more than 250 words)	3
		Achievability of Results (no more than 250 words)	3
3	Expected Results and Their Significance	Project Outcomes and Efficiency (no more than 250 words)	3
		Significance and Applicability of Expected Results (no more than 300 words)	6
4	Competence and Expertise of the Research Team	Scientific Level and Expertise of the Principal Investigator (no more than 250 words)	3
		Quality of the Research Team (no more than 250 words)	3
		Availability of Resources and Access to Infrastructure (no more than 300 words)	3
5	Interdisciplinary Nature of the Project	If the project is interdisciplinary in terms of fostering collaboration between broad scientific fields, the interdisciplinary approach is fully justified.	2
	Total		38

Table 7. Breakdown of evaluation criteria used by national expert groups.

No	Evaluation Criterion	Maximum points
1	The Degree of Impact of Research Results on the Scientific and Technical (including human resources) Potential and Competitiveness of Scientific Organizations and Their Teams, Scientists	5
2	Degree of Project Development, i.e., the Readiness of the Team to Successfully Conduct Research According to the Proposed Parameters and the Likelihood of Successful Project Implementation (taking into account the project supervisor's involvement in other projects and previous experience in leading grant-funded projects, if applicable)	5
3	Practical Significance of Research Results, i.e., the Readiness for Commercialization or Application in Addressing Current Socio-Economic and Scientific-Technical Challenges of the Republic of Kazakhstan (considering the impact of previous grant-funded projects led by the project supervisor, if applicable)	5
	Total	15

Both the international and national expert groups place significant emphasis on the potential impact of the research outcomes. International experts specifically assess the "Expected Results and Their Significance", while national experts evaluate the "Degree of Impact of Research Results" on the scientific and technical potential, including human resources and the competitiveness of the research team and organization. This shared focus highlights a common understanding of the importance of research that can contribute to scientific advancement and societal benefits. The two groups also share a concern with project feasibility and the expertise of the research team. International experts evaluate the "Competence and Expertise of the Research Team" in detail, looking at the scientific level of the principal investigator and the availability of resources and infrastructure. Similarly, national experts assess the "Degree of Project Development", which includes the readiness of the team to conduct the research and the likelihood of successful implementation. Both groups recognize the importance of ensuring that the research team is capable and well-prepared to achieve the proposed project goals. A shared focus on the project's novelty and readiness is also evident. International experts examine the "Novelty, Relevance, and Prospects of the Project", looking closely at the scientific and technical level of innovation. National experts, while not as detailed in their evaluation, consider the project's development and the team's ability to conduct the research, reflecting a similar concern for the project's readiness and potential to push the boundaries of scientific knowledge.

In our examination of 1606 projects across nine different scientific disciplines, the findings are provided in **Table 8** below.

Table 8. Correlation analysis between international and national expert groups.

No	Scientific direction	correlation between International and National expert points	Sample size	*t* statistic	critical value at 95% confidence interval
1	Geology, extraction and processing of mineral and hydrocarbon raw materials, new materials, technologies, safe products, and constructions	−0.22*	220	−3.34	1.97
2	Information, communication, and space technologies	0.07	129	0.80	1.98
3	Research in the field of education and science	0.08	153	1.01	1.98
4	Research in the field of social and humanitarian sciences	−0.06	317	−1.06	1.97
5	Life sciences and health	0.07	257	1.18	1.97
6	Sustainable development of the agro-industrial complex and agricultural product safety	−0.29*	67	−2.44	2.00
7	Energy and mechanical engineering	−0.15	138	−1.75	1.98
8	Scientific research in the field of natural sciences	−0.01	236	−0.16	1.97
9	Rational use of water resources, wildlife and flora, ecology	−0.43*	89	−4.44	1.99
	Total	−0.08*	1606	−3.33	1.96

*statistically significant at the 99% confidence interval.

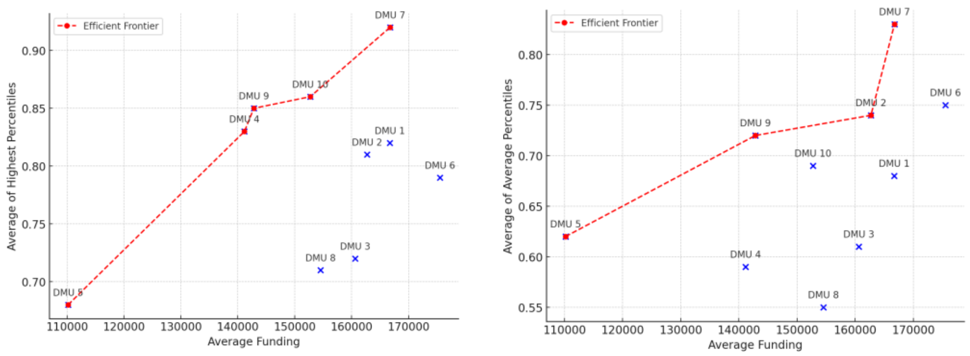
The evaluation criteria used by international and national expert groups share both similarities and differences in their focus, structure, and point allocation. Upon analyzing the criteria from both groups, it becomes clear that they align in some areas, particularly in their emphasis on research impact, team expertise, and project feasibility. However, they diverge in the granularity of their evaluation, interdisciplinary considerations, point distribution, and focus on commercialization. The correlation analysis has shown that in six scientific directions, we observe negative correlations, with half of them being statistically significant, whereas in the other three directions, there were positive correlations, but they were not statistically significant. These discipline-specific dynamics may involve differences in research culture, funding structures, or the interpretation of evaluation criteria across fields.

3.3. Influence of institutional characteristics on research project performance

Despite the limited sample size, we applied Data Envelopment Analysis, a non-parametric method, to evaluate the efficiency of the top ten organizations based on project funding. DEA was chosen for its flexibility and its ability to handle multiple inputs and outputs without requiring assumptions about the underlying data structure. This makes it particularly suited to circumstances where traditional parametric methods, such as regression, might struggle due to small sample sizes or incomplete data. In this context, DEA allows us to evaluate how efficiently organizations convert funding (the input) into research performance (the outputs). The two outputs we considered were the average of the highest project percentiles and the average of the average project percentiles for each organization, while the input was the average funding per project. DEA identifies an efficient frontier and compares each organization to this best practice, providing insights into why certain organizations may be underperforming or excelling. This method is particularly valuable when there is a need to benchmark organizational performance and assess why some perform more efficiently than others with similar resources. **Table 9** below shows the data used in the analysis.

Table 9. Sample data at the organizational level for projects implemented during the 2021–2023.

Decision making unit	Name of the organization	Number of projects	Average funding	Average of highest percentiles	Average of the average percentiles
DMU 1	Al-Farabi Kazakh National University	38	166,689	0.82	0.68
DMU 2	National Center for Biotechnology	19	162,715	0.81	0.74
DMU 3	L.N. Gumilyov Eurasian National University	17	160,636	0.72	0.61
DMU 4	Institute of Mathematics and Mathematical Modeling	13	141,171	0.83	0.59
DMU 5	E.A. Buketov Karaganda University	11	110,166	0.68	0.62
DMU 6	K.I. Satbayev Kazakh National Research Technical University	10	175,520	0.79	0.75
DMU 7	Private Institution “National Laboratory Astana”	10	166,760	0.92	0.83
DMU 8	Institute of Metallurgy and Ore Beneficiation	10	154,527	0.71	0.55
DMU 9	Nazarbayev University	9	142,822	0.85	0.72
DMU 10	Institute of Information and Computational Technologies	9	152,731	0.86	0.69
	Total	146	-	-	-



(a) **(b)**

Figure 1. Scatter plot and efficient frontier line: **(a)** output is the average of the highest percentiles; **(b)** output is the average of the average percentiles.

As indicated in the table above, out of 317 projects, data for 146 were received by 10 organizations. The remaining 171 projects were distributed among 84 different organizations with less frequency, and therefore were not included in this analysis. **Figure 1a,b** shows the efficient frontier, as well as the DMUs lying on this line, along with other DMUs below the efficient frontier. However, this is not an illustration of the efficiency scores themselves. To present the efficiency scores in a table on a scale from 0 to 1, we calculated the efficiency of each DMU based on its position relative to the Efficient Frontier. DMUs on the frontier have an efficiency score of 1 (100%), while those below the frontier have scores less than 1, calculated as the ratio of their actual output to the output of the nearest point on the frontier with the same or lower input (funding), as shown in **Table 10**.

Using the highest percentiles as the output in the first case, we found that 5 DMUs had an efficiency score of 1 for the given level of funding. Additionally, 3 out of these 5 retained the same score when the output was changed to average percentiles, while DMU 2 increased its efficiency score to 1. DMUs 4 and 10, however, showed lower efficiency scores. To better understand why the efficiency scores changed for certain organizations, further investigation into each project is required, as some projects may have an outlier impact on the average values.

Table 10. Efficiency scores for each organization with both outputs.

		Efficiency score	
Decision making unit	**Name of the organization**	**Average of highest percentiles**	**Average of the average percentiles**
DMU 1	Al-Farabi Kazakh National University	0.95	0.92
DMU 2	National Center for Biotechnology	0.94	1.0
DMU 3	L.N. Gumilyov Eurasian National University	0.84	0.85
DMU 4	Institute of Mathematics and Mathematical Modeling	1.0	0.95
DMU 5	E.A. Buketov Karaganda University	1.0	1.0
DMU 6	K.I. Satbayev Kazakh National Research Technical University	0.86	0.90
DMU 7	Private Institution "National Laboratory Astana"	1.0	1.0
DMU 8	Institute of Metallurgy and Ore Beneficiation	0.83	0.76
DMU 9	Nazarbayev University	1.0	1.0
DMU 10	Institute of Information and Computational Technologies	1.0	0.96

In summary, the application of Data Envelopment Analysis has provided valuable insights into the efficiency of research organizations in converting funding into research performance. By identifying an efficient frontier and comparing each organization's performance, we highlighted key areas where organizations either excelled or underperformed. The variation in efficiency scores, particularly when changing the output measures, suggests that further investigation into individual projects is necessary to better understand the underlying factors affecting performance. DEA proves to be a valuable tool for benchmarking institutional efficiency and guiding future resource allocation strategies.

4. Discussion

The analysis of funding levels and their impact on publication outcomes revealed several key insights. While total funding positively correlated with higher publication percentiles, the low R-squared values suggested that funding alone does not fully explain the variation in research outcomes. This finding implies that other unmeasured variables likely play a role. The significance of international expert evaluations and total funding in both the multiple and simple regression models suggests the potential influence of global expertise on high-impact research. In contrast, the negative, albeit insignificant, coefficient for national experts points to a potential misalignment between domestic evaluation criteria and internationally recognized standards of research excellence. Expanding the analysis to three years of project data, including ongoing projects, strengthened the findings by providing a larger sample size. This analysis confirms that total funding is crucial in driving research performance, especially when combined with international expert evaluations. However, the results also highlight the need to align national and international evaluation systems to improve the recognition and impact of domestic research. Further investigation is necessary to understand how expert evaluations at different levels affect long-term publication success and research impact.

As discussed in the literature review, research on grant funding often indicates that internationally aligned evaluation criteria tend to support higher research impact. Our findings resonate with this perspective, where the stronger correlation between international expert evaluations and publication percentiles suggests that international standards may positively influence research productivity in Kazakhstan. The divergence between international and national expert evaluations also underscores the distinct priorities in the evaluation process, with international experts focusing more on interdisciplinary and globally relevant outcomes, while national experts emphasize socio-economic contributions. This disparity highlights an area where alignment between local and global criteria may be beneficial, as indicated by prior studies.

The role of expert evaluations in shaping publication outcomes became clearer when comparing international and national expert groups. International expert evaluations and total funding were positively correlated with higher publication percentiles, while national expert scores were negatively correlated, though not statistically significant. This suggests that national evaluation criteria may not align with factors driving global research success. The criteria analysis revealed that while both groups emphasize research impact and team expertise, international experts prioritize interdisciplinary collaboration and global relevance, whereas national experts focus on local socio-economic outcomes. This divergence reflects different evaluation priorities, with international evaluations assessing research through a global lens and national evaluations focusing on Kazakhstan's specific challenges. These differences likely account for the contrasting correlations observed between expert evaluations and publication outcomes. There is a pressing need for greater alignment between local and global evaluation standards to maximize the research impact.

Moreover, as reviewed in the literature, biases in peer review can influence evaluation outcomes, particularly in systems with rigorous review workloads and complex selection criteria. Issues such as the "Matthew effect" and potential biases related to gender, ethnicity, and reviewer composition highlight challenges in achieving fully objective and equitable evaluations. This study does not directly examine these biases but acknowledges their potential impact, especially within the peer review processes that Kazakhstan employs. Addressing such biases could contribute to a more equitable and accurate assessment of research quality in Kazakhstan's grant evaluations.

The use of Data Envelopment Analysis (DEA) provided a valuable framework for comparing the efficiency of research organizations in converting funding into research outcomes. By identifying the efficient frontier, we demonstrated that some organizations excel in using their resources effectively, while others lag behind. The results showed that five out of the ten organizations achieved perfect efficiency when measured by the highest project percentiles, but some experienced a decline in efficiency when measured by average percentiles. This variation indicates that some institutions are better at producing consistently high-impact research, while others may excel across a broader range of projects but not in all areas. For example, DMU 2 improved its efficiency score when considering average percentiles, suggesting broader research consistency, while DMUs 4 and 10 had lower scores. This underscores the importance of considering both high-impact and average research outputs in institutional efficiency assessments. DEA has proven to be an effective benchmarking tool, allowing for nuanced comparisons across multiple performance measures. Continuous monitoring of project-level performance is essential to ensure that resources are used optimally and that organizations maintain efficiency over time.

5. Conclusion and limitations

This study provides valuable insights into the effectiveness of Kazakhstan's grant funding system by examining the influence of funding levels, evaluation criteria, and institutional efficiency on research productivity. By focusing on publication percentiles, international and national expert evaluations, and funding allocations, we address a critical need for research on grant effectiveness in emerging research environments. The findings reveal that while total funding is positively correlated with higher publication percentiles, funding alone does not fully account for variations in research outcomes, indicating the role of additional unmeasured factors. Our results also show a stronger correlation between international expert evaluations and high publication percentiles, suggesting that international standards may more effectively support high-impact research. Conversely, the less significant correlation with national expert evaluations highlights a potential area for improvement in aligning domestic evaluation criteria with internationally recognized standards.

A unique aspect of this study is the use of Data Envelopment Analysis to assess institutional efficiency. Findings show that while some research organizations excel in converting funding into high-impact publications, others display a broader consistency in research output. These insights offer an effective benchmarking framework that policymakers could use to monitor and improve organizational efficiency in research performance.

For policymakers, the study underscores the importance of balancing national priorities with internationally relevant evaluation standards. Aligning local evaluation criteria with international standards may enhance the visibility and global impact of Kazakhstani research, helping it gain greater recognition while maintaining a focus on domestic priorities. By making such adjustments, Kazakhstan can strengthen its research infrastructure, improve the quality and impact of funded projects, and foster a research environment that is competitive on an international scale.

In summary, this study contributes to the broader understanding of grant funding systems in emerging research contexts, providing actionable insights for improving grant evaluation frameworks and aligning them with globally recognized metrics. Future research would benefit from exploring additional variables that influence research productivity, such as access to collaboration networks or institutional support, to provide a more comprehensive assessment of factors driving research success in Kazakhstan and similar settings.

A central limitation of this study lies in the reliance on publication percentiles as a dependent variable. While this choice aligns with the current funding requirements and incentives in Kazakhstan, it does not necessarily serve as a definitive measure of research quality. Percentiles may reflect where a publication ranks within a journal but do not capture the broader impact, innovation, or societal relevance of the research. Consequently, the focus on high-percentile publications, though mandated by funding bodies, may not provide a comprehensive evaluation of research excellence, especially in interdisciplinary or emerging fields where impact is harder to quantify through traditional metrics.

Additionally, the accuracy and comprehensiveness of the data structure present challenges. Several publications lacked or had incorrect project numbers, making it difficult to consistently match research outputs with specific grants. In some cases, multiple projects were grouped under a single publication, which may have distorted the distribution of credit and introduced biases into the analysis. These data issues may have affected our ability to fully capture the relationship between funding, expert evaluations, and publication outcomes.

Another important limitation pertains to the structure of research funding in Kazakhstan. Up to 70% of project funding can be allocated to salaries, which may incentivize researchers to request higher levels of funding to maximize salary allowances, potentially inflating project budgets without corresponding increases in research productivity. This could skew the analysis of efficiency, particularly in cases where funding does not directly translate into proportional research output. Moreover, this study focused on projects funded during the 2021–2023 period, a relatively short time frame. Given that many of these projects are still ongoing, the full impact of the funding on publication outcomes has yet to be realized. Future research should consider extending the analysis over a longer period to capture more complete research outputs and better understand long-term trends.

Since our analysis focuses solely on funded projects, there is an inherent non-random selection process whereby the sample may overrepresent institutions and research teams with superior initial capabilities, prior performance, or greater resources. This selection process means that our findings on the impact of funding and evaluation criteria may be skewed toward higher-performing institutions, potentially limiting the generalizability of the results to all applicants or the broader research landscape.

Although econometric methods such as the Heckman selection model could address selection bias by including data from non-funded projects, such an approach requires information on unsuccessful applications and their outcomes, which is unavailable in our current dataset. Without these data, it is challenging to fully adjust for non-random selection, and our study's conclusions remain specific to the sample of funded projects.

Finally, while this study examined the role of institutional characteristics on research performance, it did not explore other potential influencing factors, such as access to international networks, institutional support systems, or collaboration opportunities. Future research should consider these variables to provide a more holistic understanding of the factors driving research success.

In conclusion, while this study offers valuable insights into the relationship between funding, expert evaluations, and research outcomes in Kazakhstan, it also highlights the limitations inherent in using publication percentiles as a primary metric. Future research should focus on incorporating more diverse measures of research quality and impact, refining data collection methods, and extending the analysis to better capture the complexities of the research environment.

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