Evaluation of Research Performance at Universities: A Comprehensive Methodological Approach

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Abstract—Evaluating the effectiveness of research activities is one of the topical issues in the higher education system. Despite this, studies on the extensive assessment of research units' outputs at the university are rare. The main goals of this study are (1) the development of a comprehensive methodology for assessing the research performance of the units; (2) testing this methodology to compare the performance indicators of 37 research institutes and centers. Both quantitative and qualitative research methods were applied in this study. Research results can be beneficiary for government bodies, allowing them to make decisions about the allocation or reallocation of funding and top management in higher education for benchmarking and internal performance evaluation of research institutes and centers. This article contributes to the theoretical basis of research performance evaluation at HEIs and puts forward a step-by-step methodology.

Keywords—research performance, assessment methodology, commercialization, efficiency of research activities

1 Introduction

The role of performance measurement in research evaluation has increased in recent years. Despite this, studies on the comprehensive assessment of the effectiveness of research units at the university are rare.

Most of the literature is devoted to different ways of evaluating research results in terms of publication, the introduction of new bibliometric indicators, comparing systems based on peer review with systems based on bibliometrics, etc. [1–6].

The use of expert review procedures is the most common model [7] and many countries have introduced their performance-based funding models. The Swedish model, along with those implemented in Poland, the Slovak Republic, and Belgium, uses article citations as one of the main inputs, while Denmark, Finland, and Norway use the number of publications [8]. In many countries (USA, UK, Italy, and Australia) special assessment systems have been developed and they are constantly being improved and adapted to the requirements of the times [9].

However, there is a distinct lack of empirical research that analyzes how researchers deal with demands for accountability [7], [10]. Research assessment systems are applied at the national, regional, and institutional levels, but very little is known about their impact on research practice. Therefore, we aim to contribute to the discussion of relationships between various research results and focus on the evaluation of the activities of research units in terms of relevance, effectiveness, cost-effectiveness, innovativeness, and potential for commercialization.

The main goals of this study are (1) the development of a comprehensive methodology for assessing the research performance of the units; (2) testing this methodology to compare the performance indicators of 37 research units.

Such results can be beneficiary for government bodies, allowing them to make decisions about the allocation or reallocation of funding, and top management in higher education for benchmarking and internal performance evaluation.

2 Literature review

Today, innovation is becoming the main driver of economic growth and a determining factor in the competitiveness of modern firms [11], regions and countries. As the experience of economically developed countries shows, the basis of a country's competitiveness is its ability to generate new knowledge and effectively transform it into innovations demanded by the economy and society. The traditional roles of universities, as knowledge producers and disseminators, are now being reconsidered. Universities have new responsibilities in transforming knowledge generated by researchers in the creation of value for socio-economic development [12].

Large amounts of public research funding in universities obligate the latter to regularly evaluate the efficiency of research activities. It will let distribute financial resources according to achieved performance and efficiency. However, from the universities' point of view, the efficiency of research activities should take into consideration not only economic and commercial effects but also scientific potential, the creation of new knowledge and knowledge dissemination.

In the last two decades, a growing number of publications have investigated the efficiency of university research. The majority of research is focused on technology and knowledge transfer efficiency or commercialization efficiency [13–17]. The literature review has shown that there are several approaches to assessing the effectiveness of research activities of universities.

2.1 A commercial approach to evaluating the effectiveness of research activities

Most of the research on evaluating the effectiveness of research activities has been carried out in the example of developed countries. In these countries, universities have long been harmoniously integrated into the innovation system and play the role of not only education, training, and research center, but also directly involved in the implementation and commercialization of research results. This is reflected in the methods of evaluating the effectiveness of research activities. In the studies carried out on the example of developed countries, the income from license agreements, the number of new companies created, their growth rates (company size: average number

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of employees, sales volume, turnover growth rates), the number of patents are used as indicators of commercialization efficiency of research results [18–21]. All these indicators directly reflect the practical impact of applying research results. However, this is only a commercial result. It is worth remembering that the purpose of research activities at universities is not always obtaining a commercial effect. Some of the studies are fundamental and their results cannot be commercialized even in the medium term. Moreover, developed countries have an enhanced infrastructure that allows them to efficiently generate income from research results permanently in the form of licensing agreements, start-up companies, etc. As for developing countries, the system of commercialization of research results is still being formed in these countries. Consequently, in developing countries, data on licensing revenues, the number of start-ups, and their growth rates are either absent or very insignificant. Therefore, the indicators of income from licensing agreements, the number of start-ups created, and their growth rates cannot be used solely to assess the effectiveness of research activities due to the lack of such data.

2.2 Approach depending on the assessment level

The existing approaches to evaluating the effectiveness of research activities are divided into two types, depending on the level of influence of research results. Within the framework of this classification, an assessment is distinguished at the micro level (at the level of the university) [22], [17], [21], the technology transfer office level [13], [14], [23] and at the macro level (at the scale of the national and regional economy [1], [24–27].

Roessner et al. [1] examined the economic impact of university licensing. Two estimates of impacts were made. One measured the impact of university licensing on GDP, and the other its impact on other industries' production (gross output) [1].

The purpose of this study is to evaluate the effectiveness of research activities at the university level. Evaluation at the macro level, at the levels of the company and technology transfer office, is beyond the scope of this study.

2.3 Methodological approaches to evaluating the efficiency of research activities

Data envelopment analysis and stochastic frontier estimation

Some efficiency studies are based on a production function framework, where a frontier of efficient combinations of inputs and outputs is constructed empirically and an organizational unit's technical inefficiency (inability to produce the maximum amount of output given one's inputs, or inability to minimize the use of inputs given one's output) is measured in terms of distance from the frontier. Such a frontier can be estimated parametrically using stochastic frontier estimation [13, 14] or non-parametrically using data envelopment analysis (DEA) [16], [22], [28]. DEA measures the efficiencies for all organizational units simultaneously, a small change in a specific variable might change the efficiency results for all organizational units. In the absence or lack of data, this disadvantage of the DEA method can become critical. Moreover, these methods of evaluating efficiency are labor–intensive and time-consuming.

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2.4 Performance-based university research evaluation systems

Citations and publication count as a measure of scientific contribution

Performance-based university research funding systems have been implemented in many European countries over the last few years [9]. The most common model is to use peer review procedures, but several countries have implemented metrics-based ex-post funding models, including Sweden. The Swedish model, together with the ones implemented in Poland, the Slovak Republic, and Flanders (in Belgium) uses citation to articles as one main input, while Denmark, Finland, and Norway use publication counts. Hammarfelt & de Rijcke [7], Andersen & Pallesen [29] also used the number of publications as an output of research activity.

Aksnes & Rip [30] also focus on the citation counts of articles and their correlation with judgments of scientific contribution. In their study Aksnes & Rip show that the citation counts of the publications correspond reasonably well with the authors' assessments of scientific contribution. Generally, citations proved to have the highest accuracy in identifying either major or minor contributions [30]. Haddow & Genoni [5] conversely supported the argument that citation data may not be the most appropriate method of assessing research output.

Some studies discussed the strengths and limitations of 'metrics' and peer review in large-scale evaluations of scholarly research performance [4, 3].

Citation and publications counts are indicators of scientific impact, contribution and productivity. But they cannot be used alone to evaluate the effectiveness of research activities. The effectiveness of research activity implies not only the formation of scientific potential and scientific impact but also the creation of innovative potential and prerequisites for the commercialization of research results.

2.5 Ranking and index research evaluation systems

Hicks [31] reviewed national ranking systems in the U.S. and Australia. The US ranking system collects information on the 48 variables. These variables concern institutional characteristics (i.e. total research expenditure, characteristics of library, childcare and health insurance availability, university housing for PhD students etc.); doctoral program characteristics (i.e. size, time to degree, financial support, facilities for PhD students, test scores, support provided, employment destinations etc.), and program faculty (size, demographics, awards, bibliometrics etc.). Also, three bibliometric variables are calculated: (1) % of faculty publishing, (2) publications/faculty, (3) citations/faculty. This ranking system is based on too many variables. As a result, it is cumbersome and complicated.

The Australian government evaluated the research in its universities using the Composite Index. This index was a formula at the university level. The formula calculated each university's share of total research activity. The components of the formula were research funding—grants from the government, other public sectors, and industry—and outputs: number of publications and graduate degrees completed (MS and PhD's) [31]. This index does not take into account the innovative potential in the form of patents and start-ups being created.

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Barker [2] in her study considered the evolution of the UK research evaluation system (The UK Research Assessment Exercise). This evaluation system is peer review-based resulting in quality ratings. Barker [2] concluded that RAE would soon be more heavily metrics-based for all subjects. The peer-review-based evaluation system is subjective as well as time-consuming. Consequently, it is not appropriate for a comprehensive evaluation of research activities.

Whitley & Gläser [8] discuss the major characteristics of national evaluation systems and how they differ between countries and over time and then considers the sorts of broad effects they are likely to have on research strategies and innovation.

Thus, a literature review showed a lack of an extensive method for evaluating the effectiveness of the university's research activities, which would combine indicators of innovation potential and, at the same time, include indicators of scientific contribution and dissemination of research results. In addition, the existing assessment methods are complex, time-consuming, and cumbersome. Thus, there is a need to develop a comprehensive as well as a simplified method for evaluating the effectiveness of research activities in the university.

3 Methodology

The research gap as the absence of a comprehensive method for evaluating research effectiveness, which would combine indicators of innovation potential as well as scientific contribution and dissemination of research results, led us to conduct current research. The present study developed a comprehensive evaluation method of research activities' efficiency in universities and evaluated the example of 37 research units.

The evaluation was performed in four consecutive steps Figure 1. Firstly, publication activity data obtained from the SciVal online platform were analyzed. Secondly, the index was calculated based on a three-factor model for evaluating the effectiveness and efficiency of research institutes, research centers, and laboratories. Third, a survey and interview in focus groups were conducted. Fourth, data was analyzed and processed and the final analytical report was prepared.

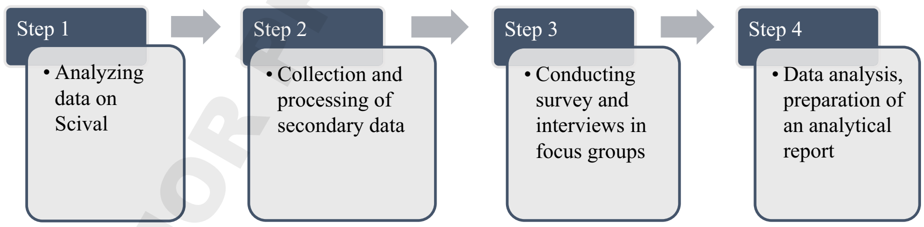

Fig. 1. Steps of evaluation of research units' performance

3.1 Analysis of publication activity using SciVal

SciVal is an online platform for monitoring and analyzing international scientific research using visualization tools and modern metrics for citation, and economic and

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social efficiency [32]. This platform enables the presentation and evaluation of the results of research activities of more than 12,000 organizations (universities, public, and corporate research centers) from 230 countries. The data source for SciVal is the Scopus database.

Using Scival, we carried out an evaluation of 37 units for 2010–2020. The following indicators were analyzed in different combinations to assess the research performance:

1) total number of publications;
2) number of citations per publication;
3) number of views of the publications;
4) Field-Weighted Citation Impact (FWCI);
5) International Collaboration – Percentage of publications (%) co-authored with researchers from other countries/regions.
6) Publications in journals 1–2 quartiles (Q1–Q2) by CiteScore by year of publication.

All data were presented in tables and infographics to ease the visual perception of research performance.

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3.2 Quantitative assessment

For the quantitative assessment of research objects, a three-factor "input-output-outcome" model was used, which allowed us to objectively compare the effectiveness of research units.

The input factors include the share of employees of the department with a scientific degree and the share of employees who have completed advanced training and have professional certificates. These factors, in turn, form the output factor – the total amount of funding received. Finally, the three factors listed above affect the outcome results, such as the number of patents, the number of publications, the number of start-ups, and the number of events held.

The data for the calculation of the index was provided by the research institutes and centers. The input parameters were taken as a percentage of the total number of employees. The output parameter was expressed in millions of tenge (national currency).

To calculate the index, each parameter was assigned a weighting factor [33]. If the overall weighting coefficient is 1, then the three factors (input-output-outcome) receive a specific weight of 0,334, 0,333, and 0,333, respectively, since each of them is assumed to have the same effect on the effectiveness of the unit. The input factor consists of two indicators, so the weight coefficient is divided by two, that is, 0,167 for each indicator. Thus, according to the degree of influence on performance, the weighting coefficient of other indicators was determined. The key parameters and weighting coefficient for each indicator are shown in Figure 2.

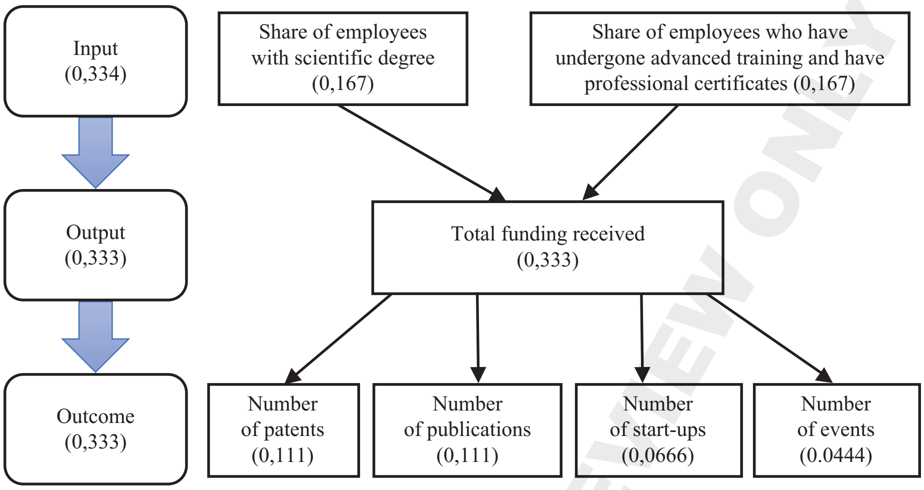

Fig. 2. Three-factor model for evaluating the effectiveness and efficiency of research institutes, research centers and laboratories

To obtain the final index, all indicators were multiplied by the corresponding weight coefficient and summed up.

The following is an example of calculating the index based on RI 05 data for 2019.

$$\text{Share of employees with scientific degree} = \frac{\text{Total number of employees with scientific degrees}}{\text{Total number of employees}} * 100\% \quad (1)$$

$$= \frac{42 + 59 + 48}{53 + 275} * 100\% = \frac{149}{328} * 100\% = 45.4\%$$

$$\text{Share of employees who have undergone advanced training and have professional certificates} = \frac{\text{The total number of employees who undergone advanced training (courses, internships, additional training)}}{\text{Total number of employees}} \quad (2)$$

$$= \frac{71 + 44}{53 + 275} * 100\% = \frac{115}{328} * 100\% = 35.1\%$$

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$$\text{Total funding received} = \left(\begin{array}{l}\text{The total amount of funding for all projects passing through the} \\ \text{accounts of University} + \text{The total amount of funding for all} \\ \text{projects that does not pass through the University accounts}\end{array}\right) = 630.16 + 670.16 = 1300.32 \text{ mln tenge} \quad (3)$$

$$\text{Number of patents} = \text{Total number of valid patents} + \text{Number of copyright certificates} = 13 + 1 = 14 \quad (4)$$

$$\text{Number of publications} = 121 + 23 + 54 + 7 + 9 + 8 + 3 = 225 \quad (5)$$

$$\text{Number of start-ups} = 0 \quad (6)$$

$$\text{Number of events} = \text{on the international level} + \text{at the republican level} = 1 + 1 = 2 \quad (7)$$

Further, the calculated values according to formulas (1)–(7) are multiplied by the corresponding weight coefficients of the indicators. As a result, we calculate the RI 05 index for 2019, which is equal to 473,06.

3.3 Questionnaire

To collect data about the commercial potential of departments and identify the most important factors that hinder the commercialization of research results, the questionnaire was conducted among units. The questionnaire allows for obtaining high-quality analytical data that helps formulate proposals for further improving the work of research institutes, centers, and laboratories of the university.

7 large research institutes, a science and technology park, and 29 research centers were chosen as objects of study. The share of the natural and technical direction at these units prevails, so the sample distribution based on the survey results is reasonable. The number of respondents was 203. Answers were given anonymously.

Apart from introductory questions highlighting the background of the respondents, the following questions were asked using a Likert scale from 1 to 5:

1. Rate the current state of the infrastructure required for scientific research.
2. Evaluate the contribution of the following parties to the support of your R&D to obtain the result and (or) bring it to the commercialization stage.
3. Assess your professional development over the past 3 years according to the following criteria.
4. Assess the impact of the main barriers to the commercialization of R&D results at the micro level.
5. Assess the impact of the main barriers to the commercialization of R&D results at the macro level.

Data were processed by the SPSS program to test hypotheses.

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3.4 Interview in focus-groups

The final stage of monitoring the activities of research institutes, centers, and laboratories was conducting interviews in focus groups. Focus group interviews are a flexible information-gathering tool that leads to reliable conclusions as a result of data processing.

The focus group approach offers the opportunity of allowing people to probe each other's reasons for holding a certain view. For one thing, an individual may answer in a certain way during a focus group, but, as he or she listens to others' answers, he or she may want to qualify or modify a view; alternatively may want to voice agreement to something that he or she probably would not have thought of without the opportunity of hearing the views of others. These possibilities mean that focus groups may also be very helpful in the elicitation of a wide variety of views concerning a particular issue [34].

The purpose of the interview was to identify factors that hinder the effective commercialization of research results in the university and systematize proposals and recommendations to eliminate or minimize these factors.

The interview was conducted in 3 streams on the Zoom platform. Centers of the natural-technical direction, socio-humanitarian direction, and research institutes and laboratories were interviewed separately. The interview was attended by heads of departments, representatives of the Center for Strategic Development, and members of the working group. The average interview time in focus groups was 90–120 minutes. During the interview, the participants were asked questions about the processes of commercialization of research results, the effectiveness of departments, barriers and problems limiting the effectiveness and efficiency of activities, specific proposals, and recommendations to improve the efficiency.

4 Results

4.1 Results of the analysis of publication activity using SciVal

According to the first stage based on SciVal data, publication activity of 8 scientific-research institutes steadily raises, while citations per publication decreased. It suggests that the number of publications cannot be used as the only indicator of the effectiveness of research activities. Publications number may grow, but this does not indicate the quality of publications. Therefore, citations count to supplement the information and give a more complete picture.

Also, the FWCI indicator for almost all eight research institutes is either unstable or almost unchanged. It suggests that despite the growth of publication activity, the contribution to world science and the influence of scientific publications on a global and sectoral scale is almost imperceptible. Such unchanged meanings of FWCI may reflect sluggish interest from the world scientific and expert community.

Besides, the share of publications co-authored with foreign scientists (%), to a certain extent, reflects the quality of publications.

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The percentage of publications in Q1–Q2 journals according to CiteScore is also a fairly valid indicator of the effectiveness and efficiency of the university's research activities. Some departments lead in publishing activity but lag in terms of the share of publications in Q1–Q2 journals. This again suggests that performance indicators change when considering different types of research results. When comparing the effectiveness according to publication activity and share of publications in Q1–Q2 journals, it turns out that the same department is evaluated differently. According to publication activity, this department is effective, and according to publications share in Q1–Q2 journals, the same department is already assigned a low indicator. Thus, publication activity should not be considered alone but together with such indicators as citations per publications, FWCI, the share of publications co-authored with foreign scientists, and the share of publications in Q1–Q2 journals.

We considered such different types of research results as the number of publications, citations per publication, FWCI, the share of publications co-authored with foreign scientists, and the share of publications in Q1–Q2 journals. Not all scientific departments that have an increase in publication activity have the same increase in citations. The same department is evaluated differently depending on different research results used for evaluation purposes.

As for units on natural and technical direction, they have published more articles in Q1–Q2 journals than the research institutes. It again suggests that different output parameters lead to differences in the evaluation of research results. When considering publication activity only, research institutes would show high results but when taking into account publications in Q1–Q2 journals, the picture of efficiency changes and the natural-technical profile already demonstrates no less efficiency.

4.2 Results of quantitative assessment

The quantitative assessment using a three-factor model was carried out for the following groups for 2018–2021:

1. Research Institutes (RI)
2. Research Centers of natural and technical direction (RCNTD)
3. Research Centers of socio-humanitarian direction (RCSHD)

Some research centers began to function after 2018, so data are not available for them.

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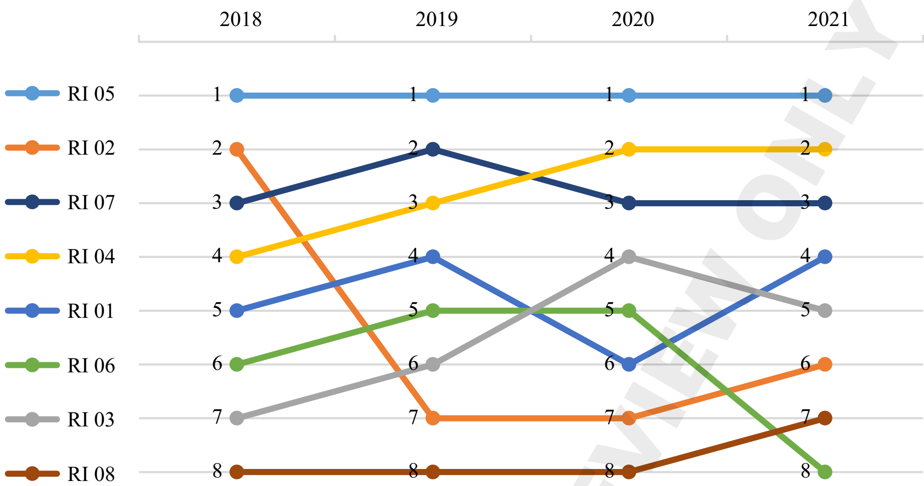

Fig. 3. Ranking of research institutes based on the results of the analysis

As can be seen from Figure 3, RI 05 is the permanent leader in the ranking, and the performance of this research institute is about three times higher than others. It is due not only to a large number of funded projects but also to the high quality of the human capital that is involved in the implementation of these projects and shows high performance.

Since 2019, RI 02 has shown low efficiency due to a decrease in labor productivity per employee, while RI 03, on the contrary, having increased this indicator, improved its position in the ranking.

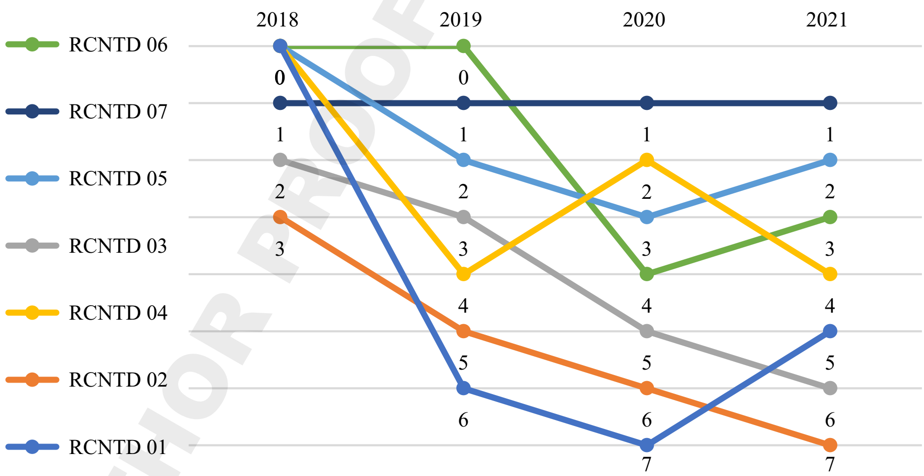

Fig. 4. Ranking of research centers of the natural and technical direction based on the results of the analysis

In 2018, only 3 research centers of the natural and technical direction functioned. In 2020, their number reached 7. For all the analyzed years, RCNTD 07 showed the best

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results and It maintained its position despite the emergence of new esearch centers in this direction. s is because all employees of this center annually take advanced training courses both at the republican and international levels. RCNTD 04 was founded in 2019, and RCNTD 06 in 2020 showed average results for the year of operation, that is, they started from 4th place and gradually improve their positions. RCNTD 01 and RCNTD 02 replace each other in the last positions due to a lack of funding and, as a result, low outcome indicators Figure 4.

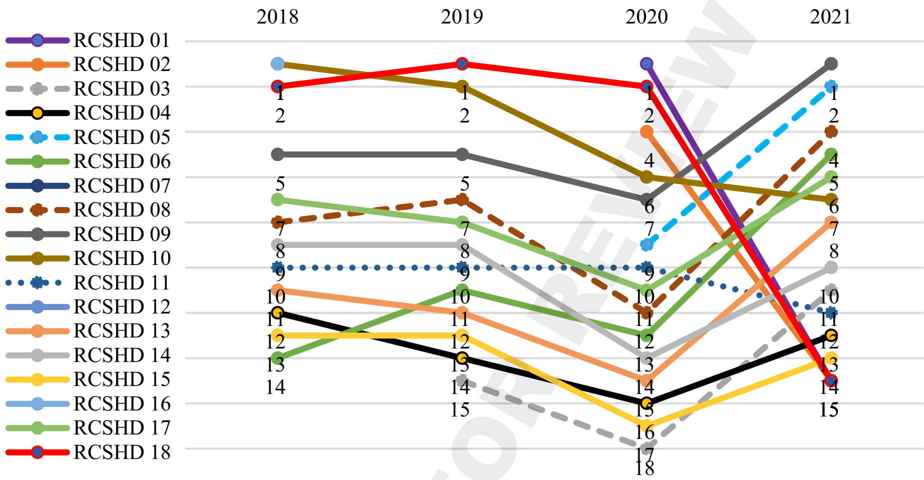

Fig. 5. Ranking of scientific centers of the socio-humanitarian direction based on the results of the analysis

The rating ranked 18 research centers of the socio-humanitarian direction Figure 5. Due to the large number of centers, it is difficult to determine one center that shows the best results in dynamics. It can be noted that the RCSHD 16, which occupied a leading position in 2018–2020, was in last place in 2021. For 2021, four centers have zero value: RCSHD 01, RCSHD 02, RCSHD 16, RCSHD 18.

4.3 Results of the questionnaire

Most of the respondents belong to the age group of 20 to 40 years. 70% of respondents are researchers, and about 19% are heads of departments. More than half of the respondents (about 63%) have scientific degrees. The composition of the respondents is mainly represented by the natural and technical direction.

Regarding the current state of the scientific infrastructure, the majority of respondents noted good access to scientific information and the good state of the information and telecommunications infrastructure. However, the state of the main scientific equipment, software, and the situation with consumables and components were noted by the majority of respondents as satisfactory. This suggests that there is potential for improving these elements of the scientific infrastructure.

All departments and structures of the university fully accompany R&D / R&D to obtain the final result and (or) bring it to the stage of commercialization. However,

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according to the majority of respondents, third-party organizations do not take part in R&D support. Concerning professional development, about a quarter of respondents noted a satisfactory level of experience in the commercialization of intellectual property. The remaining skills and competencies are at the highest and intermediate levels.

According to the respondents, the most important barriers that have a strong impact on the R&D commercialization processes are bureaucracy, insufficient funding for research, insufficient material incentives for employees, outdated material and technical base, and the absence/underdevelopment of accompanying services. Such barriers at the micro level as the lack of preliminary market analysis, the lack of skills to "pack" knowledge into a product, the lack of conditions to support start-up and spin-off companies, the insufficient development of an organizational culture aimed at stimulating innovative and creative thinking caused difficulties for a certain part of the respondents. This may indicate a lack of skills in these areas.

According to the results of the survey, all barriers at the macro level, except for shortcomings in the system of protection of intellectual property, have a strong influence on the processes of R&D commercialization. It should be noted that the proportion of respondents who found it difficult to answer regarding barriers at the macro level is significant. The choice of research topics was determined mainly by the study of foreign literature, compliance with the priority areas of science, and continuation of dissertation research topics. The smallest proportion of research topics was determined by the request from the enterprises or by the results of market research/demand identification. This fact suggests that taking into account market demand is in last place among the factors influencing the choice of R&D topics.

Additionally, we conducted an analysis of the survey results using the SPSS program. To assess the reliability of our questionnaire, a model was used using the Alpha (Cronbach) coefficient, which shows an internal consistency model based on average point-to-point correlation (Table 1).

Table 1. Reliability of questionnaire

Reliability Statistics		**Note**
Alpha (Cronbach) coefficient	N	
0,921	38	All variables with ordinal scales
0,871	5	Variables related to the assessment of scientific infrastructure (question 5)
0,794	4	Variables related to assessing the contribution of structures to R&D support (question 6)
0,879	8	Variables related to the professional development of an employee (question 7)
0,913	11	Variables related to assessing the impact of barriers at the micro level (question 8)
0,934	10	Variables related to assessing the impact of barriers at the macro level (question 9)

As can be seen from Table 1, Cronbach's alpha for all variables takes values > 0.7, which demonstrates the reliability of the questionnaire.

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The analysis of contingency tables (crosstabs) was carried out for the following variables:

1. Relationship between research direction and assessment of scientific infrastructure.

The hypothesis that there is a relationship between the direction of research and the assessment of scientific infrastructure was confirmed only for the first variable INFR_ONO. That is, there is a difference in the vision of the state of the main scientific equipment between representatives of the natural-technical and social-humanitarian areas.

For the remaining variables, Pearson's Chi-squared result was $p \geq 0.05$, meaning they are not statistically significant. This means that in assessing the remaining elements of the scientific infrastructure, there is no significant difference between representatives of the natural-technical and social-humanitarian areas.

2. The relationship between the direction of the study and the assessment of the impact of barriers at the micro level.

The hypothesis about the presence of a relationship between the direction of research and the assessment of the impact of barriers at the macro level was confirmed only for the BMIC_MATTEX variable. This means that the evaluation of other barriers at the micro level occurred evenly.

3. The relationship between the direction of the study and the assessment of the impact of barriers at the macro level.

The hypothesis about the existence of a relationship between the direction of research and the assessment of the impact of barriers at the macro level was confirmed only for the BMAC_ZAVOD variable. This can be explained by the need for platforms for scaling prototypes only for representatives of the natural and technical profile.This means that the assessment of other barriers at the macro level occurred evenly.

The contingency tables constructed between the age of respondents and professional development revealed statistically significant indicators only for the item "Knowledge of English". Statistics confirm that respondents in the 20–40 category have a better command of English. Similar cross-tabulations were constructed between research direction and professional development factors. $p \leq 0.05$ was found only for the parameter "Knowledge of English". As the analysis shows, representatives of the natural-technical direction have a better command of English.

Cross tables for other parameters did not reveal significant differences in the answers of different age categories.

4.4 Focus-group results

The purpose of the focus group interviews was to identify factors that hinder the effective commercialization of research results and systematize suggestions and recommendations for their elimination or minimization.

As a result of conducting interviews in focus groups, we identified barriers to the effective commercialization of research results in three groups of divisions: natural-technical, socio-humanitarian, as well as research institutes. The identified barriers were classified into financial, organizational, infrastructural, material and technical,

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personnel ones. It is worth noting that barriers in general are common for all groups of divisions. However, for the natural-technical direction, the barriers associated with material and technical equipment are more critical. Table 2 contains key barriers and suggestions for eliminating or minimizing these barriers.

Table 2. Key barriers to effective commercialization and proposals to eliminate or minimize them

Problems	Recommendations and Suggestions
Organizational structure	
Bureaucratic barriers in the execution of applications and contracts	Simplification of document flow, reduction of bureaucratic procedures, development of the university's own procurement and payment policy.
Scientific infrastructure and material and technical support	
Obsolescence of the material and technical base	Determination of the responsible structure for collecting and processing requests for updating the material and technical base, provision of a separate fund to finance the purchase and repair of basic equipment
Weak collaboration between departments	Opening a laboratory for collective use; strengthening collaboration between departments through joint research projects and co-supervision of graduate works
Financial issues	
Limited additional sources of financing for innovative projects	Creation of an Innovation Support Fund to finance pilot tests
Lack of funding for the creation of startup and spin-off companies based at the university	Provision of a mechanism for creating corporate startups on the basis of the university: the university can invest in startups in return for a share in the authorized capital.
Bureaucracy in financial transactions	Development of own procurement and payment policy
Human resources potential	
Insufficient support of commercially promising developments	Involving a professional commercialization manager to each commercially promising development
Insufficiency of mechanisms in the indicative plan that stimulate the commercialization of R&D.	Stimulating the desire of scientists to commercialize research results by reflecting the results of commercialization in personal ratings
Project support and consulting	
Absence of a structure accompanying the process of commercialization of R&D results	Creation of a Commercialization Center at the university, attracting highly qualified personnel with competitive salaries to the center. Assignment of incentive payments depending on the volume of commercialized products and services.
Miscellaneous	
Low awareness of teaching staff and researchers about the scientific research of other faculties and departments	Organization of guest lectures by scientists-inventors in the Science talks format to disseminate information about successful cases of R&D commercialization Development of interdisciplinary interaction of scientists, departments and faculties
Weak cooperation with representatives of the industrial sector	Opening of joint laboratories of the university with interested industrial enterprises

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Thus, interviews in focus groups revealed the key barriers to the effective commercialization of research results obtained at the university. Most of the barriers are related to bureaucratic processes, the effectiveness of financing mechanisms, and staffing. Staffing problems are mainly related to the lack of qualified and professional commercialization managers who could accompany the process of bringing research results to the market. The main proposals for improving commercialization processes were a simplification of document flow, reduction of bureaucratic procedures, creation of corporate start-ups based at the university, attachment of a professional commercialization manager to each commercially promising development, and creation of a Commercialization center at the university.

5 Discussion

The methodology developed in the current study, in contrast to studies that previously evaluated the effectiveness of research activities, differs in that this methodology is a step-by-step, comprehensive one and includes both quantitative and qualitative assessment methods. The proposed three-factor model includes input and output indicators and simultaneously takes into account scientific potential in the form of publications number and other indicators from SciVal, dissemination of research results in the form of several events, and commercialization potential in the form of intellectual property rights, and startups. It is worth noting that the effectiveness of scientific activities of universities and research institutes should consider not only the economic effect of research results but also the increase in scientific potential, productivity, and dissemination of research results.

Moreover, this methodology also includes qualitative analysis based on questionnaires and interviews in focus groups. All previously performed studies on the assessment of the effectiveness of research activity were conducted based on one or two indicators, that is, they were not comprehensive and did not take into account the commercialization potential. An exploratory literature review shows that the proposed methodology developed within the framework of this study for evaluating the effectiveness of scientific activity is distinctive.

This step-by-step methodology will be useful for the management of higher education institutions, research institutes, and centers for internal analysis and performance evaluation purposes. It is also of interest to the state bodies for the distribution and redistribution of financial resources directed to research.

6 Conclusion

The current research performance at higher education institutions is characterized by a tension between administrative demands for more straightforward measures and simpler assessment methods, while researchers demand fair evaluation of their activities. Our study consisted of two stages: 1) developing a comprehensive methodology for a fair evaluation of research units in terms of their efficiency; 2) conducting an empirical study based on the data from 37 research institutes and centers located in Almaty,

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Kazakhstan. Their performance was examined using both quantitative and qualitative methods.

We assume that this empirical study allows us to analyze whether research institutes and centers respond to market demands, how efficient their activities are, and whether public and private funding allocated to research projects is justified.

For further research, it would be interesting to develop a similar methodology for evaluating effectiveness separately for basic and applied research. The nature of these studies and the expected results from them vary. Accordingly, when evaluating the effectiveness of these types of research, it is necessary to consider various input and output indicators. Additionally, it would be useful to develop a specially adapted methodology for evaluating research effectiveness in the social and humanitarian direction. It is also possible to study how the assessment methodology developed in this study can affect the strategy of research activities.

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8 References

[1] D. Roessner, J. Bond, S. Okubo, and M. Planting, "The economic impact of licensed commercialized inventions originating in university research." *Research Policy*, vol. 42, no. 1, pp. 23–34, 2013, https://doi.org/10.1016/j.respol.2012.04.015

[2] K. Barker, "The UK research assessment exercise: the evolution of a national research evaluation system." *Research Evaluation*, vol. 16, no. 1, pp. 3–12, 2007, https://doi.org/10.3152/095820207X190674

[3] H. F. Moed, "The future of research evaluation rests with an intelligent combination of advanced metrics and transparent peer review." *Science and Public Policy*, vol. 34, no. 8, pp. 575–583, 2007, https://doi.org/10.3152/030234207X255179

[4] S. Harnad, "Validating research performance metrics against peer rankings." *Ethics in Science and Environmental Politics*, vol. 8, no. 1, pp. 103–107, 2008, https://doi.org/10.3354/esep00088

[5] G. Haddow and P. Genoni, "Citation analysis and peer ranking of Australian social science journals." *Scientometrics*, vol. 85, no. 2, pp. 471–487, 2010, https://doi.org/10.1007/s11192-010-0198-4

[6] A. Sala, P. Landoni, and R. Verganti, "R&D networks: an evaluation framework." *International Journal of Technology Management*, vol. 53, no. 1, pp. 19–43, 2011, https://doi.org/10.1504/IJTM.2011.037236

[7] B. Hammarfelt and S. De Rijcke, "Accountability in context: effects of research evaluation systems on publication practices, disciplinary norms, and individual working routines in the faculty of Arts at Uppsala University." *Research Evaluation*, vol. 24, no. 1, pp. 63–77, 2014, https://doi.org/10.1093/reseval/rvu029

[8] R. Whitley and J. Gläser, *The Changing Governance of the Sciences*. Springer Science & Business Media, 2008.

AUTHOR PROOF FOR REVIEW ONLY

[9] D. Hicks, "Performance-based university research funding systems." *Research Policy*, vol. 41, no. 2, pp. 251–261, 2012, https://doi.org/10.1016/j.respol.2011.09.007
[10] R. Zhou, "Establishment and study of an evaluation model for the exploitation effect of university scientific and technological patents." *International Journal of Emerging Technologies in Learning (iJET)*, vol. 17, no. 20, pp. 231–247, 2022, https://doi.org/10.3991/ijet.v17i20.34525
[11] A. Da Silva Alcantara, "An application of a gamified approach to learning of knowledge management: evaluation of an experience report." *International Journal of Emerging Technologies in Learning (iJET)*, vol. 17, no. 19, pp. 87–134, 2022, https://doi.org/10.3991/ijet.v17i19.32665
[12] G. Secundo, C. De Beer, and G. Passiante, "Measuring university technology transfer efficiency: a maturity level approach." *Measuring Business Excellence*, vol. 20, no. 3, pp. 42–54, 2016, https://doi.org/10.1108/MBE-03-2016-0018
[13] D. S. Siegel, D. A. Waldman, L. E. Atwater, and A. N. Link, "Toward a model of the effective transfer of scientific knowledge from academicians to practitioners: qualitative evidence from the commercialization of university technologies." *Journal of Engineering and Technology Management*, vol. 21, no. 1, pp. 115–142, 2004, https://doi.org/10.1016/j.jengtecman.2003.12.006
[14] D. S. Siegel, R. Veugelers, and M. Wright, "Technology transfer offices and commercialization of university intellectual property: performance and policy implications." *Oxford Review of Economic Policy*, vol. 23, no. 4, pp. 640–660, 2007, https://doi.org/10.1093/oxrep/grm036
[15] J. B. Powers and P. P. McDougall, "University start-up formation and technology licensing with firms that go public: a resource-based view of academic entrepreneurship." *Journal of Business Venturing*, vol. 20, no. 3, pp. 291–311, 2005, https://doi.org/10.1016/j.jbusvent.2003.12.008
[16] J. G. Thursby and S. Kemp, "Growth and productive efficiency of university intellectual property licensing." *Research Policy*, vol. 31, no. 1, pp. 109–124, 2002, https://doi.org/10.1016/S0048-7333(00)00160-8
[17] T. Vinig and D. Lips, "Measuring the performance of university technology transfer using meta data approach: the case of Dutch universities." *The Journal of Technology Transfer*, vol. 40, no. 6, pp. 1034–1049, 2015, https://doi.org/10.1007/s10961-014-9389-0
[18] S. Jacobsson, Åsa Lindholm-Dahlstrand, and L. Elg, "Is the commercialization of European academic R&D weak?—A critical assessment of a dominant belief and associated policy responses." *Research Policy*, vol. 42, no. 4, pp. 874–885, 2013, https://doi.org/10.1016/j.respol.2013.01.005
[19] M. Gulbrandsen and E. Rasmussen, "The use and development of indicators for the commercialisation of university research in a national support programme." *Technology Analysis & Strategic Management*, vol. 24, no. 5, pp. 481–495, 2012, https://doi.org/10.1080/09537325.2012.674670
[20] S. Shane, "Selling university technology: patterns from MIT." *Management Science*, vol. 48, no. 1, pp. 122–137, 2002, https://doi.org/10.1287/mnsc.48.1.122.14281
[21] M. J. Alvarado-Vargas, S. K. Callaway, and S. Ariss, "Explaining innovation outputs by different types of R&D inputs: evidence from US universities." *Journal of Strategy and Management*, vol. 10, no. 3, pp. 326–341, 2017, https://doi.org/10.1108/JSMA-09-2015-0077
[22] F. Rossi, "The drivers of efficient knowledge transfer performance: evidence from British universities." *Cambridge Journal of Economics*, vol. 42, no. 3, pp. 729–755, 2017, https://doi.org/10.1093/cje/bex054

AUTHOR PROOF FOR REVIEW ONLY

[23] P. M. Swamidass and V. Vulasa, "Why university inventions rarely produce income? Bottlenecks in university technology transfer." *The Journal of Technology Transfer*, vol. 34, no. 4, pp. 343–363, 2008, https://doi.org/10.1007/s10961-008-9097-8
[24] J. Guan and K. Chen, "Measuring the innovation production process: a cross-region empirical study of China's high-tech innovations." *Technovation*, vol. 30, no. 5, pp. 348–358, 2010, https://doi.org/10.1016/j.technovation.2010.02.001
[25] K. Chen and J. Guan, "Measuring the efficiency of China's regional innovation systems: application of network data envelopment analysis (DEA)," *Regional Studies*, vol. 46, no. 3, pp. 355–377, 2012, https://doi.org/10.1080/00343404.2010.497479
[26] J. Guan and K. Chen, "Modeling the relative efficiency of national innovation systems." *Research Policy*, vol. 41, no. 1, pp. 102–115, 2012, https://doi.org/10.1016/j.respol.2011.07.001
[27] D. Kalmakova, Y. Bilan, A. Zhidebekkyzy, and R. Sagiyeva, "Commercialization of conventional and sustainability-oriented innovations: a comparative systematic literature review." *Problems and Perspectives in Management*, vol. 19, no. 1, pp. 340–353, 2021, https://doi.org/10.21511/ppm.19(1).2021.29
[28] J. G. Thursby and M. C. Thursby, "Who is selling the Ivory Tower? Sources of growth in university licensing." *Management Science*, vol. 48, no. 1, pp. 90–104, 2002, https://doi.org/10.1287/mnsc.48.1.90.14271
[29] L. B. Andersen and T. Pallesen, "'Not just for the money?' How financial incentives affect the number of publications at Danish research institutions." *International Public Management Journal*, vol. 11, no. 1, pp. 28–47, 2008, https://doi.org/10.1080/10967490801887889
[30] D. W. Aksnes and A. Rip, "Researchers' perceptions of citations." *Research Policy*, vol. 38, no. 6, pp. 895–905, 2009, https://doi.org/10.1016/j.respol.2009.02.001
[31] D. Hicks, "Evolving regimes of multi-university research evaluation." *Higher Education*, vol. 57, no. 4, pp. 393–404, https://doi.org/10.1007/s10734-008-9154-0
[32] Elsevier.com. 2022. *SciVal | Navigate the world of research with a ready-to-use solution |Elsevier Solutions*. [Online]. Available: https://www.elsevier.com/solutions/scival?dgcid=RN_AGCM_Sourced_300005487
[33] A. Zhidebekkyzy, R. Sagiyeva, and Z. Temerbulatova, "Assessing the competitiveness of Kazakhstan regions: creating an index." *E3S Web of Conferences*, vol. 159, no. 10, p. 05002, 2020, https://doi.org/10.1051/e3sconf/202015905002
[34] A. Bryman and E. Bell, *Business Research Methods*. Oxford University Press, USA, 2007.

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