Development of higher education in Russian regions:
the number of scientific and pedagogical staff

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Abstract
This study was devoted to the assessment of indicators characterizing the number and structure of research and teaching staff at universities and other institutions of higher education in the regions of Russia. These indicators were the number of teachers working in higher education, per thousand residents and per hundred students, proportion of professors and associate professors in the whole number of teachers. Research used official statistical information for 82 regions of Russia. We used density functions of normal distribution as models. Study showed that on average, there was a little more than one teacher working in higher education organizations per thousand residents. It is proved that on average, every seventh teacher in all regions held the position of professor. Approximately two-thirds of all teachers held associate professor positions, there were five teachers per one hundred students.

Keywords
Higher Education; Number of Teachers; Number of Students; Regions of Russia.

Desenvolvimento do ensino superior nas regiões da Rússia:
o número de pessoal científico e pedagógico

Resumo
O estudo foi dedicado à avaliação de indicadores que caracterizam o número e a estrutura do pessoal científico e pedagógico de universidades e outras instituições de ensino superior nas regiões da Rússia. Esses indicadores foram o número de professores que trabalham em instituições de ensino superior por mil residentes e por cem estudantes, a proporção de professores e professores associados no número total de professores. O estudo utilizou informações estatísticas oficiais sobre 82 regiões da Rússia. Usaram-se funções de densidade de distribuição normal como modelos. O estudo constatou que, em média, por mil residentes, pouco mais de um membro do corpo docente trabalhava em organizações de ensino superior. Está provado que, em média, um em cada sete professores em todas as regiões ocupou o cargo de professor. Aproximadamente dois terços de todos os professores ocupavam cargos de professor assistente, com cem alunos representando cinco professores.

Palavras-chave
Ensino Superior; Número de Professores; Número de Alunos; Regiões da Rússia.

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Desarrollo de la educación superior en las regiones de Rusia:

número de personal científico y pedagógico

Resumen
El estudio se centró en la evaluación de los indicadores que caracterizan el número y la estructura del personal científico y pedagógico de las universidades y otras instituciones de educación superior en las regiones de Rusia. Estos indicadores eran el número de profesores que trabajaban en instituciones de educación superior, por cada mil habitantes y por cada cien estudiantes, la proporción de profesores y profesores asociados en el total de profesores. El estudio utilizó información estadística oficial sobre 82 regiones de Rusia. Utilizamos las funciones de densidad de distribución normal como modelos. El estudio encontró que, en promedio, por cada mil habitantes, poco más de un maestro trabajaba en organizaciones de educación superior. Se ha demostrado que, en promedio, uno de cada siete maestros en todas las regiones ocupó el cargo de profesor. Aproximadamente dos tercios de todos los profesores ocupaban puestos de profesores asociados, con un total de cinco profesores por cada cien estudiantes.

Palabras clave
Educación Superior; Número de Profesores; Número de Estudiantes; Regiones de Rusia.

1 Introduction

The increasing role of higher education, as indicated in the classical work (JASPERS, 1960), contributes to the significant social and economic development of modern states. In developed and developing countries, both universities and other institutions of higher education have become widespread (CRUZ NEYRA; TOLEDO ESPINOZA; MENDONZA RAMÍREZ, 2021; MIRANDA; AZEVEDO, 2020).

In the twenty-first century, most States have created conditions that ensure mass access of the population to higher education (GURI-ROSENBLIT; SEBKOVA; TEICHLER, 2007). The total number of students in all countries in 2016 was 218 million, which is 1.5 times more than in 2006 (LA MOBILITE INTERNATIONALE, 2019). To solve the problems of higher education, a necessary condition is the availability of scientific and pedagogical personnel capable of teaching students according to appropriate programs. Taking this into account, one of the urgent scientific problems is the assessment of indicators characterizing presence of personnel, that is, professors, associate professors, as well as other categories of teachers who ensure the availability of higher education (DOUGLAS, 2011; STIGLITZ, 2014). Our research was devoted to this issue. Studying

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the current level of solving this problem is important both for state bodies regulating activities in this area, and directly for potential students.

Despite the existence of extensive research on the problem of the development of higher education, until now, not enough attention has been paid to the regional peculiarities of solving this problem. The presence of organizations in the regions that teach students according to the relevant programs, as indicated in the works (ABEL; DEITZ, 2011; CIRIACI, 2014), increases the attractiveness of the regions, positively affects their economic growth and, most importantly, ensures the retention of school graduates in the regional labor market. All this determines the increased interest in the study of regional aspects of the development of higher education. Our article responds to the calls made in several scientific publications (for example, CERVANTES, 2017; HUAMAN CAMILLO; IBARGUEN CUEVA; MENACHO, 2020; SIANES-BAUTISTA, 2021; UNGER; POLT, 2017) to study the existing features of higher education by region. To date, sphere of higher education in Russia has received significant development. In 2020, there were 1259 specialized organizations operating in this industry. Total number of teachers working at universities and other institutions of higher education was 223088 people. Of these, 35039 are professors, and 129328 are associate professors (FEDERAL STATE STATISTICS SERVICE, 2021).

The purpose of our study was to evaluate the indicators characterizing the number and structure of research and teaching staff at universities and other institutions of higher education in the regions of Russia. Our paper is aimed at obtaining a certain empirical and methodological contribution to the knowledge about the presence in the regions of science personnel that teach students in higher education programs. This contribution consists in the fact that the author's method of modeling the estimation of the number of professors and teachers in universities and other institutions of higher education in the regions of Russia using the density functions of the normal distribution is proposed. The empirical contribution is related to the determination of the average values and standard deviations by region of such indicators as number of teachers, working at universities and higher education institutions, per thousand residents of the region, proportion of professors in the whole number of teachers, proportion of associate professors in the whole number of teachers, number of teachers, per hundred students. In addition, the regions with the maximum and minimum values of these indicators are determined.
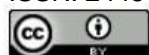
The structure of this work is below. The following section provides an overview of scientific publications of recent years that characterize such aspects of higher education as the number and structure of teachers in Russia, as well as the ratio of the number of teachers and students. The methodology, initial data and design of the study described in our article are presented below. The following sections present the simulation results and their discussion. The last sections contain conclusions and bibliographic references.

A number of scientific publications published in recent years have been devoted to the problem of assessing such an aspect of the development of higher education in Russia as the number and structure of the scientific and pedagogical staff of higher education organizations, as well as the current ratio of the number of teachers and students. A brief description of these publications is given in Table 1.

Table 1 – Scientific publications on the activities of scientific and pedagogical staff

Authors	Problems	Objects	Indicator type
Anisimova and Babich (2016)	Estimation of the number of students per teacher in higher education institutions in 2010-2014	Russia	Relative
Maksimova (2019)	Change in the number of teaching staff in higher education organizations for 2005-2018	Russian regions	Absolute
Kurilova (2020)	Analysis of changes in the number of research staff at universities in 2015-2019	Russia	Absolute
Vlasova (2021)	Dynamics in number of person in higher educational activities	Russia	Absolute
Lomonosov (2013)	Justification of the optimal standard number of faculty staff	Russia	Absolute
Romanov (2018)	Financing the remuneration of teachers who teach students under bachelor's and master's degree programs in 2016-2017	Russia	Absolute
Popova and Vdovina (2017)	The number of professors and teachers at universities in 2017	Penza region	Absolute
Vadimova (2015)	Dynamics of changes in the number of students per teacher for the period from 2012 to 2015	Russia	Relative
Vardanyan and Keshishyan (2020)	Analysis of the teachers number in higher education who had academic degrees in 2014-2018	Russia	Absolute
Kirillina (2015)	Study of the ratio of the number of students and the number of research and teaching staff at universities according to data for 2007-2012 per teacher for the period from 2012 to 2015	Russia	Relative
Melikyan (2021)	Trends in the growth share of teachers with an academic degree in the total number of employees in the Russian higher education system	535 universities	Index

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Source: The table is compiled by the author on the basis of the information provided in the RSCI (SCIENCE ELECTRONIC LIBRARY, 2021).

Based on the information given in Table 1, it can be stated that the problem of research on the number and structure of teachers who carry out training in higher education programs is relevant in Russia. Most of the studies reviewed analyzed the number of teachers, students and the number of organizations in Russia as a whole. At the same time, a comprehensive assessment of the distribution of the number and structure of teachers according to all regions of Russia has not been sufficiently reflected in scientific publications. It can be noted that a comparative analysis of relative indicators that allow us to assess the regional characteristics of higher education organizations was not carried out in most studies. Thus, absolute indicators were given in 70% of the studies indicated in the table. Taking this into account, it seems appropriate to conduct a comparative analysis of the existing relative (specific) indicators characterizing the achieved level of activity of scientific and teaching staff in all regions of Russia.

2 Methodology

The scientific and pedagogical staff of higher education organizations, the number and structure of which is considered in this article, carried out training of students in 2020 the bachelor (four years of study), specialist degree (five years of study), as well as master's degree programs were taken into account.

The research process included five stages. At the first stage, initial data were formed that characterize the number of universities and other institutions of higher education and the number of research and teaching staff by region in 2020, as well as the number of students enrolled in higher education programs this year. In addition, empirical data on the number of inhabitants in these regions were formed. At the second stage, indicators were calculated that characterize the number of teachers per thousand residents of each of the regions and the specific weights of professors and associate professors in the total number of teachers of higher education organizations, as well as the number of teachers per one hundred students. At the third stage, the distribution of indicators by region was evaluated based on the development of mathematical models. At the fourth

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stage, the average values of indicators for the regions of Russia were determined, as well as the ranges in which the values of these indicators are located for most of them.

The study used official statistical information of the Ministry of Science and Higher Education of the Russian Federation for 2020 on the number of higher education organizations and the number of teachers in these organizations in 82 regions of Russia (OFFICIAL…, 2021). In addition, we used empirical data from the Federal State Statistics Service of Russia on the population for each of the regions in 2020 (FEDERAL STATE STATISTICS SERVICE, 2021).

In our study, three hypotheses were tested:

hypothesis 1 - the scientific and pedagogical staff providing training for students in higher education programs is currently present in all regions of Russia;

hypothesis 2 - the values of indicators by region have a small variation, that is, they are homogeneous;

hypothesis 3 - the regions characterized by the maximum and minimum values of each of the four indicators are located in different federal districts.

The evaluation of the values of the four considered indicators was carried out on the basis of economic and mathematical modeling of the initial empirical data. As models, we used the density functions of the normal distribution, the method of developing which for estimating the values of relative indicators was proposed by the author. Some aspects of the use of the methodology are given in the works (PINKOVETSKAIA; SLEPOVA, 2018; PINKOVETSKAIA *et al.*, 2021). During the development of the functions, the initial empirical data were grouped according to the ranges of changes in the values of the indicators. These data groups can be geometrically represented in the form of corresponding histograms. Data approximation using normal distribution functions was carried out using generally accepted statistical methods. It is important to note that the average values of the considered indicators, as well as their standard deviations for the density functions of the normal distribution, are in the formulas of the developed functions themselves. Therefore, by constructing a specific function, we get the specified parameters of the considered indicators without additional calculations.

The obtained functions allowed us to determine the average values of each of the four indicators for the regions under consideration, as well as the ranges of their changes

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characteristic of most regions. In addition, the study identified regions in which the considered indicators have values above the upper and below the lower boundaries of the ranges. The boundaries of the indicator ranges for 68% of the regions were determined based on the average values of the indicators and the corresponding standard deviations. The lower bound of the interval is equal to the difference between the mean and the standard deviation, and the upper bound is equal to their sum.

3 Results and discussion

In the course of the computational experiment, economic and mathematical modeling was carried out on the basis of empirical data. The models that describe the distributions (y_1 ; y_2 ; y_3 ; y_4) of the four indicators (x_1 ; x_2 , %; x_3 , %; x_4) across all 82 Russian regions are shown below:

- the number of teachers, working at universities and higher education institutions, per thousand residents of the region

$$y_1(x_1) = \frac{51.3}{0.6 \times \sqrt{2\pi}} \cdot e^{-\frac{(x_1-1.2)^2}{2\times0.6\times0.6}} ; \qquad (1)$$

- the proportion of professors in the number of teachers working at universities and higher education institutions

$$y_2(x_2) = \frac{192.4}{3.0 \times \sqrt{2\pi}} \cdot e^{-\frac{(x_2-13.8)^2}{2\times3.0\times3.0}} ; \qquad (2)$$

- the proportion of associate professors in the number of teachers working at universities and higher education institutions

$$y_3(x_3) = \frac{303.8}{6.5 \times \sqrt{2\pi}} \cdot e^{-\frac{(x_3-61.1)^2}{2\times6.5\times6.5}} ; \qquad (3)$$

- the number of teachers, working at universities and higher education institutions, per hundred students

$$y_4(x_4) = \frac{55.7}{1.2 \times \sqrt{2\pi}} \cdot e^{-\frac{(x_4-5.0)^2}{2\times1.2\times1.2}} . \qquad (4)$$

The quality of functions (1)-(4) we tested using such criteria: by the Kolmogorov-

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Smirnov, the Pearson and the Shapiro-Wilk. Calculated values of criteria are given in Table 2.

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Table 2 – Calculated values of criteria

Function number	Test		
	Kolmogorov-Smirnov	Pearson	Shapiro-Wilk
(1)	0.05	3.55	0.95
(2)	0.03	1.70	0.96
(3)	0.03	1.02	0.95
(4)	0.04	4.50	0.98

Source: The data in the table are based on the results of calculated functions.

Information given in column 2 of Table 2 showed that all calculated values are less than the critical value by the Kolmogorov-Smirnov test (0.174) at significant level equal 0.05. Data in column 3 are less than critical value of Pearson criterion (9.49). Data in column 4 exceed critical value 0.93 Shapiro-Wilk test with significant level of 0.01. Thus, the computational experiment showed that all four developed functions have high quality.

At the next stage of the study, the values of indicators characterizing the number and structure of scientific and pedagogical personnel working at universities and other institutions of higher education in the regions of Russia were determined. The values of the indicators, the average by region, are shown in column 2 of Table 3. The average values were determined on the base of functions (1)-(4). The third column indicates the standard deviation for discussing indicators. The values of the indicators characterizing the upper and lower boundaries of the intervals corresponding to the majority of regions are shown in column 4. We calculate the lower limits as the difference between the average value and the standard deviation, and we calculate the upper limits as the sum of the average value and the standard deviation.

Table 3 – Values of indicators describing the saturation of Russian regions with teachers working at universities and higher education institutions

Indicator numbers	Average values	Standard deviation	For most regions
The number of teachers, working at universities and higher education institutions, per thousand residents	1.2	0.6	0.6-1.8
The proportion of professors in the number of teachers working at universities and higher education institutions, %	13.8	3.0	10.8-16.8
The proportion of associate professors in the number of teachers working at universities and higher education institutions, %	61.1	6.5	54.6-67.6
The number of teachers, working at universities and higher education institutions, per hundred students	5.0	1.2	3.8-6.2

Source: Author's calculations on the basis of functions (1)-(4).

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An analysis of empirical data for 2020 showed that there are higher education organizations in all 82 regions of Russia. Accordingly, the scientific and teaching staff was also in each of the regions. Thus, the first hypothesis was confirmed. The data in table 3 show that the average number of teachers working in universities and higher education institutions by region is 1.2 per thousand inhabitants. In most regions, this indicator ranges from 0.6 to 1.8. On average, the share of professors in the number of teachers working at universities and higher education institutions in the regions is 13.8% of the total number of teachers of higher education organizations. That is, about every seventh teacher has the academic title of professor. The values of indicators for most regions range from 10.8% to 16.8%. The average value for the regions of Russia of the share of associate professors in the number of teachers working at universities and higher education institutions in 2020 was more than 61% of the total number of teachers of higher education organizations. The values of this indicator, typical for most regions, were in the range from 55% to 67%. It should be noted that in Russian universities and other institutions of higher education, the number of associate professors is 4.3 times more than teachers who have a professor's degree. The average number of teachers working in universities and higher education institutions, accounting for one hundred students, was 5. The values of these indicators, typical for most regions, were in the range from 4 to 6%. That is, typical for Russian regions is from 25 to 17 students per teacher. This is slightly more than the average values for OECD countries, which range from 10 to 20 students per teacher (OECD/UIS/EUROSTAT, 2019).

To test hypothesis 2 on the differentiation of indicators by region, an analysis of the degree of variation of each of the indicators presented in Table 3 was carried out. To do this, we used the standard deviations shown in column 3. The variation indices are as follows: for the first indicator - 50%, for the second indicator - 22%, for the third indicator - 11%, for the fourth indicator - 24%. This analysis showed that there was no significant (more than 33%) differentiation of values for three of the four indicators in the regions under consideration. That is, hypothesis 2 about the homogeneity of the values of indicators by region was partially confirmed.

The next step was to determine the regions of Russia in which the maximum and minimum values of each indicator were marked. In this case, the maximum values are those that exceed the upper limits of the ranges specified in column 4 of Table 3, and the minimum values are those that are less than the lower limits of the specified ranges. The results of this

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analysis are shown in Table 4. Along with the lists of regions, this table also shows the values of indicators by region, as well as which of the federal districts the regions belong to.

Table 4 – Characteristics of Russian regions with maximum and minimum indicator values

(to be continued)

Indicators	Region	Value	Federal district
	With maximum values of indicators		
The number of teachers, working at universities and higher education institutions, per thousand residents of the region	Oryol region	1.8	Central
	Mordovia republic	1.8	Privolzhsky
	Novosibirsk region	1.8	Siberian
	Tatarstan republic	1.8	Privolzhsky
	North Osetia-Alania republic	1.9	North Caucasian
	Voronezh region	2.0	Central
	Tomsk region	3.4	Siberian
	Moscow city	3.7	Central
	Saint Petersburg city	3.9	North-West
	With minimum values of indicators		
	Chukotka autonomous district	0.1	Far Eastern
	Leningrad region	0.1	North-West
	Sakhalin region	0.3	Far Eastern
	Jewish autonomous region	0.4	Far Eastern
	Murmansk region	0.5	North-West
	Moscow region	0.5	Central
	Kamchatka territory	0.5	Far Eastern
	Ingushetia republic	0.6	North Caucasian
	With maximum values of indicators		
The proportion of professors in the number of teachers working at universities and higher education institutions	Tula region	16.8%	Central
	Voronezh region	17.2%	Central
	Tambov region	17.2%	Central
	Leningrad region	17.4%	North-West
	Ivanovo region	17.6%	Central
	Kursk region	17.6%	Central
	Moscow city	18.3%	Central
	St. Petersburg city	18.3%	North-West
	Saratov region	19.0%	Privolzhsky
	Kabardino-Balkar republic	19.2%	North Caucasian
	Tomsk region	19.3%	Siberian
	Novgorod region	19.6%	North-West
	With minimum values of indicators		
	Tyva republic	5.4%	Siberian
	Altai republic	7.9%	Siberian
	Kamchatka territory	8.2%	Far Eastern
	Karachay-Cherkess republic	8.3%	North Caucasian
	Kurgan region	8.9%	Ural
	Primorsky territory	9.4%	Far Eastern
	Sevastopol city	9.5%	South
	Khakassia republic	9.6%	Siberian
	Pskov region	9.9%	North-West
	Komi republic	10.2%	North-West
	Sakha Republic	10.4%	Far Eastern

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Table 4 – Characteristics of Russian regions with maximum and minimum indicator values

(conclusion)

	With maximum values of indicators		
The proportion of associate professors in the number of teachers working at universities and higher education institutions	Tambov region	67.7%	Central
	Stavropol territory	67.8%	North Caucasian
	Bryansk region	68.2%	Central
	Kirov region	68.6%	Privolzhsky
	Crimea republic	69.0%	South
	Orel region	69.5%	Central
	Altai republic	70.3%	Siberian
	Mordovia republic	70.5%	Privolzhsky
	Jewish autonomous region	72.1%	Far Eastern
	Adygea republic	72.8%	North Caucasian
	Chukotka autonomous territory	75.0%	Far Eastern
	With minimum values of indicators		
	Novosibirsk region	49.8%	Siberian
	Tyva republic	50.5%	Siberian
	Kostroma region	50.9%	Central
	Primorsky territory	52.2%	Far Eastern
	Sakha republic	52.5%	Far Eastern
	Moscow city	52.8%	Central
	Moscow region	53.4%	Central
	Sevastopol city	53.6%	South
	Sverdlovsk region	54.0%	Ural
	Karelia republic	54.3%	North-West
	Khabarovsk territory	54.3%	Far Eastern
	Chechen republic	54.6%	North Caucasian
	Sakhalin region	54.6%	Far Eastern
	With maximum values of indicators		
The number of teachers, working at universities and higher education institutions, per hundred students	Tomsk region	6.3	Siberian
	Ivanovo region	6.3	Central
	Moscow city	6.4	Central
	Sakha republic	6.4	Far Eastern
	Primorsky territory	6.5	Far Eastern
	Tver region	6.5	Central
	North Ossetia-Alania republic	6.6	North Caucasian
	Krasnoyarsk territory	6.7	Siberian
	Saint Petersburg city	6.8	North-West
	Karelia republic	6.8	North-West
	Crimea republic	7.3	South
	With minimum values of indicators		
	Sakhalin region	2.8	Far Eastern
	Chukotka autonomous district	2.9	Far Eastern
	Chechen republic	3.1	North Caucasian
	Jewish autonomous region	3.5	Far Eastern
	Kamchatka territory	3.6	Far Eastern
	Chuvash republic	3.7	Privolzhsky
	Tula region	3.8	Central
	Ingushetia republic	3.8	North Caucasian

Source: Developed by the author on the basis of data from Table 3.

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Table 4 provides information on the values of indicators for each of the regions (column 3), as well as their territorial location (column 4). The analysis of this information showed that there is no connection between the maximum and minimum values of the indicators and the territorial location of the regions. That is, the regions with high and low values of indicators are located in different federal districts. Thus, we can state the confirmation of hypothesis 3.

5 Final considerations

In general, it should be noted that our research makes a number of important contributions to the knowledge of the territorial features of the development of higher education in Russia. The purpose of our study was to evaluate the indicators characterizing the number and structure of research and teaching staff at universities and other institutions of higher education in the regions of Russia. The conclusions that have scientific novelty and originality are given below. First, it was found that teachers worked in 2020 in higher education organizations that were located in all 82 regions of Russia without exception. Accordingly, residents of each of the regions could study in an accessible proximity to their place of residence. In the course of the study, a method was proposed for evaluating four indicators that characterize the activity of teachers in higher education organizations using the density functions of the normal distribution. Based on the proposed methodology, the distribution of the corresponding indicators was estimated for all 82 regions of Russia. The results of the computational experiment showed that on average, there was a little more than one teacher working in higher education organizations per thousand residents in the regions. It is proved that on average, every seventh teacher in all regions held the academic title of professor. Approximately two-thirds of all teachers held associate professor academic title. In universities and institutes of higher education, on average, there were five teachers per one hundred students in the regions.

The analysis showed that there was no significant differentiation of the values of the three indicators by region. Only the indicator number of teachers working at universities and higher education institutions, per thousand residents of the region, had a significant differentiation by region. The regions that were characterized by the maximum and minimum values of the four considered indicators were identified. The study showed

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that the territorial location of the regions does not significantly affect the maximum and minimum values of the indicators.

The practical significance of the study for the government is to take into account the territorial features in the development of higher education in the regions of Russia. The results of the work can be used in the activities of federal and regional structures related to the support of educational processes, when justifying their planned activities, improving the quality of higher education by increasing the share of highly qualified teachers. For potential students, data on the distribution of research and teaching staff by region may be of particular interest.

The proposed methodology for modeling the estimation of the number of teaching staff can be used in conducting research on the development of higher education in countries with a large number of administrative units (states, provinces, regions, districts). In particular, in the BRICS countries.

The new knowledge gained is of interest and can be used in the educational process at universities. The study was not limited to empirical data, as it was based on official statistical information for all 82 regions of Russia. Further research may be aimed at establishing gender characteristics describing the number and structure of teachers in higher education organizations in Russia.

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