European Journal of Contemporary Education
E-ISSN 2305-6746
2023. 12(3): 874-884
DOI: 10.13187/ejced.2023.3.874
https://ejce.cherkasgu.press

Retrospective Analysis and Features of the Dynamics of Main Indicators in Training of Higher Qualification Personnel

Elena E. Kabanova [a, *]

[a] Financial University under the Government of the Russian Federation, Moscow, Russian Federation

Abstract

Innovative development is a key factor in the technological sovereignty and competitiveness of the Russian economy on a global scale, especially in the face of sanctions pressure from unfriendly states. A critical resource that defines competitive advantage in the modern world is knowledge, the central role in the formation of which is held by human capital. Workers with higher education are the foundation of human capital relied upon by the innovation economy, fundamental and applied scientific research, and research and technological development. The study of quantitative and qualitative dynamics in the provision of higher qualification staff allows for assessing the innovative potential of the national economy, which determines the relevance of this direction of research. The established objective is fulfilled in the study through a review of statistical indicators characterizing the training of higher qualification personnel in Russia. With the use of mathematical and statistical methods, analysis, synthesis and descriptive methods, a retrospective analysis of the dynamics of basic indicators has been carried out that have a direct impact on the innovative potential of the Russian economy. The connection was evaluated between innovative processes and the personnel support of the research sector.

The study reveals that despite some qualitative success in recent years, there is a slight overall decline in the quantitative characteristics of higher qualification staff training, which negatively affects the intellectual capital of the country as a whole and reduces opportunities in the innovative development of the economy. This can impair the country's intellectual capital overall and reduce opportunities for research and development and the implementation of new technology in the economy. The retrospective analysis also confirms the detrimental impact of the higher education system reform from the point of existing qualitative statistical indicators.

Keywords: postgraduate studies, doctoral studies, innovative development, intellectual capital, retrospective analysis, human capital.

* Corresponding author
E-mail addresses: cool90@list.ru (E.E. Kabanova)

1. Introduction

Higher qualification personnel are a critical link in the training and provision of staff for the national science, higher school, and strategic sectors of the economy (Kelsina, 2018; Malichenko, 2019). The innovative development policy is primarily driven by research work and personnel capable of generating new ideas in this field (Latkin, Trotsenko, 2020). In other words, the availability of enough people able to generate new ideas and invent new technology is a vital precondition for the innovative development of the economy (Gurtov i dr., 2022; Terent'ev i dr., 2018). For this reason, the study of primary statistical indicators of personnel training in higher education is a topical research task (Argilov, 2022; Kuvshinov, Chempalova, 2019).

In existing studies, as a rule, the authors turn to either only one characteristic of the functioning of the training of high school personnel (number of graduates), or use static data for individual years as an illustration of ongoing processes in the field of higher education. Also, researchers in their works do not conduct assessments of the influence of the dynamics of indicators of the training system of higher education on the indicators of innovative activities in the economy. In the presented article, these deficiencies will be eliminated.

The established system of training of higher qualification personnel remained principally unchanged for decades in the time of the USSR, serving as a fundamental and stable source of scientific and pedagogical personnel for the national economy. However, after the collapse of the Soviet Union, the prestige and quality of postgraduate education dropped (Bednii i dr., 2017; Mironenko, 2018). In particular, N.I. Bednyi points to a fact specific to Russia – a sharp rise in the number of postgraduate students against the decline of scientific personnel. This suggests a logical conclusion that the association between postgraduate education and success in research and development (R&D). The researcher notes that trends in the development of the postgraduate and scientific research sectors turned out to diverge (Bednii, Ribakov, 2022). Despite some positive changes in this sphere, the ratio of postgraduate students to professional researchers is still far even from that in the mid-1990s. Although the number of postgraduate students has declined significantly since 2010, it remains higher than that of researchers, which has been consistently reducing since 1992 (Bednii, Ribakov, 2022). Here we should clarify that between 2000 and 2021, with an overall decline in the number of R&D staff, the number of persons with secondary vocational or other education had decreased by a factor of 2 or more. In turn, the number of researchers with higher education has hardly changed in 20 years (Vlasova i dr., 2023).

Thus, despite the rising number of higher education graduates, the level of Russian science, including on the world scale, remained rather low since the 1990s and could not serve as a basis for technological breakthroughs in the economy (Barabash i dr., 2017). This fact has entailed a series of successive changes to the system of training of scientific and pedagogical staff in the past decade (Latkin, Trotsenko, 2020). The results of these reforms are rather ambiguously interpreted by Russian researchers (Bednii, Ribakov, 2022; Kapshutar, 2016; Krasinskaya, Klimova, 2020). Stricter requirements of the Higher Attestation Commission have led to negative trends in the form of quantitative and qualitative decline in the indicators of training of senior professionals (Vellem, 2023; Martinova i dr., 2019; Senchenko, 2015). In particular, one of the bases for criticism of the training system is the low share of postgraduates defending dissertations (Terent'ev i dr., 2018; Afanasev i dr., 2023; Zerchaninova, Tarbeeva, 2019). The ongoing changes have not yet shown significant improvement in this matter. On the one hand, the reforms were intended to improve the quality of dissertations (Pahomov i dr., 2019), which is the exact reason for the lower number of successful defenses among the graduates of postgraduate and doctoral programs (Ignat'ev, 2021). However, this has resulted in a larger gap between Russia and developed countries in the relative share of postgraduate students in the total population, which was already quite low before (Bednii, Ribakov, 2022).

2. Methods

To perform a retrospective assessment of the dynamics of main indicators of higher qualification personnel training in Russia, the study uses data provided by Rosstat (Federal'naya sluzhba...; Obrazovanie v Rossii..., 2003; Rossiiskii statisticheskii ezhegodnik..., 1996) and the Higher School of Economics (Vlasova i dr., 2023). To process the presented data arrays, a descriptive method, mathematical and statistical methods, analysis and synthesis were used. For the most complete and objective presentation of the results obtained, graphical and tabular methods were utilized.

Highly qualified personnel include persons who have mastered the third level of higher education, and who subsequently, having received an academic degree, are engaged in teaching and research activities. The most important indicator of the functioning of the institute of higher education is the number of researchers with academic degrees, since they play a key role in shaping innovation processes in the economy, so the first part of the current work is devoted to a retrospective study of the dynamics of the number of researchers.

The key parameters of the functioning of the system of higher qualification personnel training are data on their number and admission to and graduation from postgraduate and doctoral programs, as well as the structure of graduates by the main branches of science. The second part of this article is devoted to the study of the dynamics of these statistical indicators.

3. Discussion

The uncontrollable explosive rise of the primary indicators of higher qualification personnel training in the 1990s and 2000s was not accompanied by a greater quality of work in Russian science and education. On the contrary, this increase resulted in the fall of the prestige of academic degrees among the general public. This effect was also aggravated by the widespread plagiarism and diminished scientific value of dissertations. In part, these problems have survived to this day (Mironenko, 2018), although considerable work has been carried out in the past decade to reform the postgraduate education system to improve the quality of training of higher qualification personnel.

Unfortunately, the ongoing changes cannot be considered entirely positive, since against the background of a slight increase in the relative proportion of dissertation defenses, there has been a precipitous drop in the number of postgraduate and doctoral students enrolled and graduating. Other statistical indicators that would allow us to track changes in qualitative indicators (e.g., the scientific value of candidate and doctoral dissertations) are not provided. This fact greatly complicates the objective assessment of the ongoing transformation of higher education.

It is worth noting that the results of reforms are more noticeable in the results of doctoral studies: in this area, the share of graduates with defended dissertations has increased dramatically since 2017 and has almost reached the indicators of the mid-1990s. The number of doctoral students has now decreased fivefold compared to its peak in 2013. Reduction is observed in the number of those entering and completing doctoral studies (Bychkova, Timoshenko, 2018). To somewhat paraphrase E.A. Terent'ev (Terent'ev i dr., 2018), this will eventually entail the lack of a “critical mass of people with higher qualification”, the latter being a critical precondition for the global competitiveness of Russia. The average age of researchers with a doctoral degree has risen from 60 to 64 between 2000 and 2021 (Vlasova i dr., 2023). The sharp drop in the number of doctoral graduates will cause further increases in the average age of researchers with higher academic degrees. This fact cannot but raise justified concerns about the future of Russian science. At the same time, it should be noted the "overflow" of scientific personnel from natural and technical fields into the humanitarian and public scientific sphere, which negatively affected the indicators of innovation activity in the Russian industry.

4. Results

The training of higher qualification personnel describes the work of postgraduate and doctoral schools: admission and graduation, as well as the number of postgraduate students and doctors. The dynamics of these primary indicators allow assessing prospects for the development of Russian higher education relying both on current data and retrospective analysis of statistical indicators.

As mentioned above, one of the factors in the competitiveness of Russia in the global knowledge economy is the availability of enough people with higher qualifications (Terent'ev i dr., 2018). Here we refer to researchers with the academic degrees of candidates and doctors of science. Thus, the starting point for the study is data on the dynamics of the factual amount of researchers in the past decades, which are illustrated in Figure 1.

Figure 1 shows that since 1990, there has been a continuous downward trend in the number of workers directly engaged in scientific R&D. The period of the most dramatic decline was in the first half of the 1990s. After that, the reduction of staff has been gradually slowing down, although it has preserved its negative nature up to the present day.

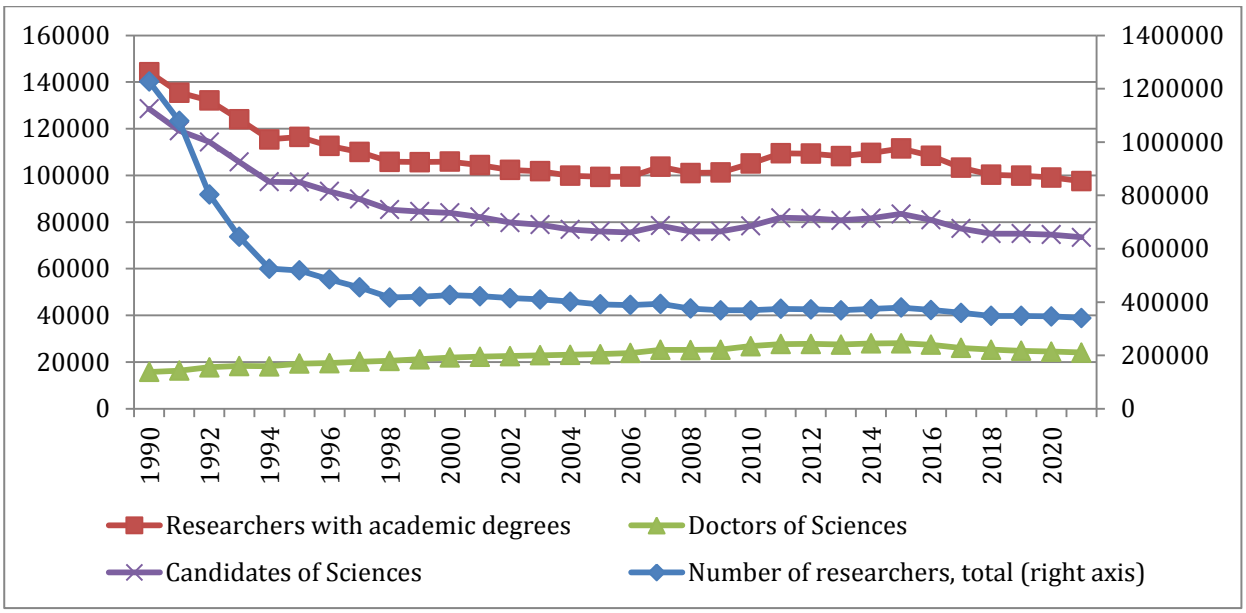

Fig. 1. Dynamics of the number of researchers, including those with academic degrees, persons (Source: compiled by the author according to (Vlasova i dr., 2023a; Federal'naya sluzhba...; Obrazovanie v Rossii..., 2003; Rossiiskii statisticheskii ezhegodnik..., 1996)

In the second half of the 2010s, the reduction of research personnel with degrees began, which had a negative impact on the innovative development of the country, primarily in the industrial sector. These processes are illustrated in Figure 2.

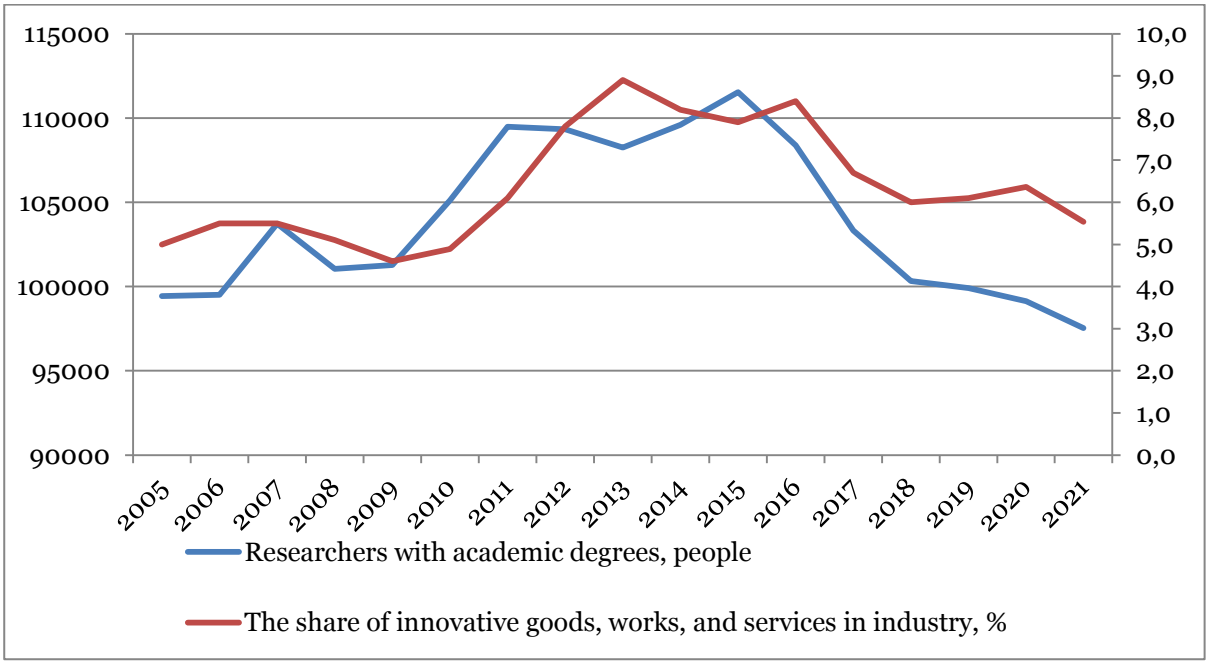

Fig. 2. Dynamics of the number of researchers, including those with academic degrees, people (Federal'naya sluzhba...)

As can be seen from Figure 2, there is a similarity in the dynamics between the change in the number of researchers and the share of innovative products in the industry. Therefore, we can confidently say that the lack of an innovative breakthrough in the Russian economy is largely due to the shortage of research personnel, which is clearly demonstrated to us in Figure 2.

S.V. Istomina also in her work, along with other active factors, established a regression relationship between the share of innovative products and the share of researchers with an

academic degree (Istomina i dr., 2018). However, it is worth checking out a similar dependence not only on the relative proportion of researchers with degrees, but also on their absolute number, since, as we said above, to ensure the competitiveness of the domestic economy, a "critical mass of highly qualified people" is needed. In addition, it is worth noting that S.V. Istomina operates only with the period 2006–2015, which reduces the reliability of the regression equation obtained by her due to the limited sample. In the current work, the period 2005–2021 is considered with a large number of observations (17 vs. 10), which increases the reliability of the correlation analysis. Of course, Figure 2 is not enough for a confident conclusion about the correlation of indicators. Let's move on to estimates by statistical methods.

The equation of paired linear regression of the dependence of the share of innovative products in industry on the absolute number of researchers with scientific degrees for the period 2005–2021 is as follows:

$$Y = 88309{,}686+2446{,}1449X, \text{ where}$$

Y – the share of innovative goods, works and services in industry;

X – number of researchers with scientific degrees.

The correlation coefficient is 0.724, the coefficient of determination is 0.525. The significance of F and the P-value of the variable X take values of 0.001 (with the actual value of the Fisher criterion of 16.56 and the tabular value of 4.54), which indicates a sufficiently high reliability and statistical significance of the obtained regression model. Thus, an increase in the number of researchers with scientific degrees by 2,446 people leads to an increase in the share of innovative goods, works and services in the industrial sector by 1 %.

The data obtained indicate a high dependence of innovation processes in the industrial sector on the dynamics of the number of researchers. And that a qualitative innovation breakthrough in the Russian economy should be based, first of all, on scientific personnel. Now let's move on to the assessment of the structural dynamics of changes in the number of higher school personnel.

It is worth noting that the number of researchers with academic degrees has reduced relatively little and has been roughly constant since the mid-2000s – this has a consequence in the stagnation of the share of innovative products. This reduction, however, affected primarily workers with candidate degrees. In contrast, the number of doctoral candidates in academia has had a marked increase over the past 30 years, contrary to the trend observed among researchers. While in 1990, there were 15,739 researchers with doctoral degrees, by 2021 there were only 24,074, with 128,547 and 73,463 candidates, respectively. To estimate relative indicators, the share of doctors of sciences has grown 5.5 times, and the proportion of candidates – 2.1 times (Figure 3).

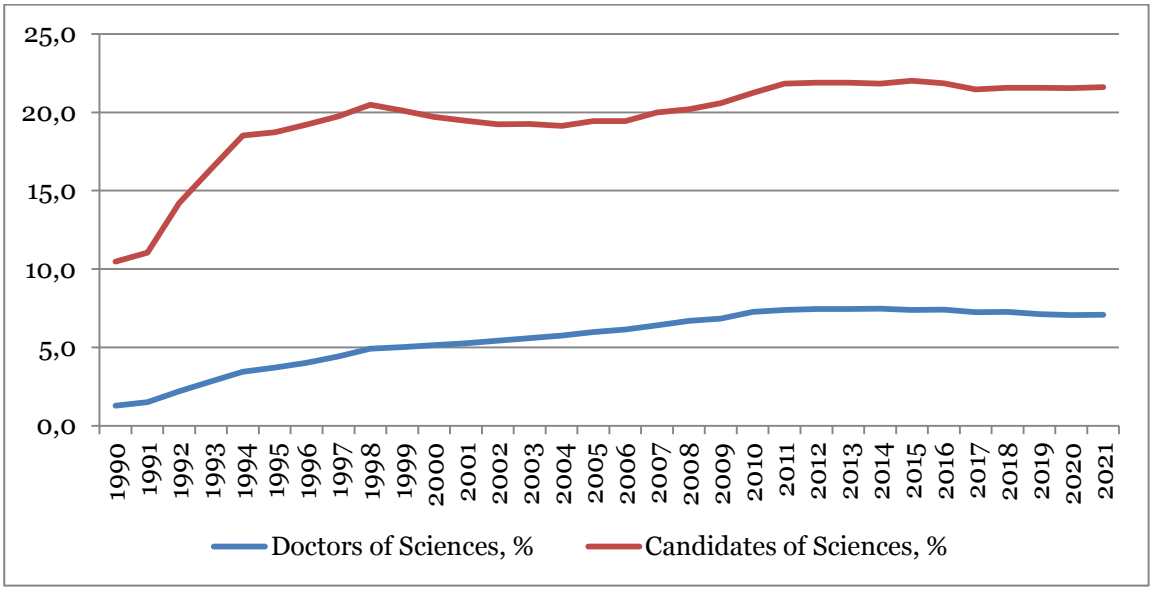

Fig. 3. Dynamics of the share of researchers with academic degrees, % of the total number (Source: compiled by the author according to (Vlasova i dr., 2023a; Federal'naya sluzhba...; Obrazovanie v Rossii..., 2003; Rossiiskii statisticheskii ezhegodnik..., 1996)

The proportion of candidates had its maximum growth rate in 1990–1998, although this increase owed to a considerable decline in science workers without academic degrees. Next followed a period of relatively stable change in the number of researchers overall and those with candidate degrees in particular. In contrast, the share of doctors of sciences had a continuous rise until 2010, after which it has been steadily decreasing.

Thus, in the past 30 years, the R&D community has seen a major increase in the number of scientific workers with academic degrees. The greatest phase of relative growth occurred in the 1990s when the least valuable employees without degrees were the first to be dismissed.

Now, let us consider the work of postgraduate schools in terms of the number of postgraduate students and the statistics of admission and graduation.

Table 1. Dynamics of the number of postgraduate students, admission and graduation from postgraduate programs, persons

Year	Number of postgraduates at the end of the year	Admission	Graduation from postgraduate programs		Share of graduates who defended their dissertations, %
			total	with thesis defense	
1970	66,600	n.d.	17,100	3,300	19
1980	66,642	19,600	16,596	2,800	17
1990	63,156	17,500	16,336	3,500	21
1992	51,915	13,865	14,857	3,135	21
1995	62,317	24,025	11,369	2,609	23
2000	117,714	43,100	24,828	7,503	30
2005	142,899	46,896	33,561	10,650	32
2010	157,437	54,558	33,763	9,611	28
2011	156,279	50,582	33,082	9,635	29
2012	146,754	45,556	35,162	9,195	26
2013	132,002	38,971	34,733	8,979	26
2014	119,868	32,981	28,273	5,189	18
2015	109,936	31,647	25,826	4,651	18
2016	98,352	26,421	25,992	3,730	14
2017	93,523	26,081	18,069	2,320	13
2018	90,823	27,008	17,729	2,198	12
2019	84,265	24,912	15,453	1,629	11
2020	87,751	27,710	13,957	1,245	9
2021	90,156	27,992	14,326	1,500	10
2022	109,705	45,075	13,865	1,791	13

Source: compiled by the author according to (Vlasova i dr., 2023a; Federal'naya sluzhba...; Obrazovanie v Rossii..., 2003; Rossiiskii statisticheskii ezhegodnik..., 1996).

If we consider the number of graduates with defended dissertations as an indicator of the quality of work of postgraduate schools, Table 1 offers interesting information. Until the collapse of the USSR, this indicator was markedly stable, and from 1995 to 2005, it saw a considerable rise in the number of defended theses. Essentially, the system of training of higher qualification personnel had been working stably for decades and demonstrating an upward trend. Yet reforms of the past decades intended to improve the situation have, on the contrary, had an extremely negative impact on the quality of work of postgraduate schools. The number of graduates with successfully defended dissertations has reduced to significant values on the scale of the past 50 years. In this, of key importance is not so much lowering the relative share of defenses as the reduction of their factual number – since the peak of 2005, the number of defenses has declined 6 times. This is approximately half of the Soviet average of 1970–1990 (about 3,000 annually). As follows from Figure 1, candidates of sciences are already part of the scientific community that has undergone significant cuts over the past 30 years. Such a noticeable drop in the number of graduates

defending their doctoral theses will further worsen the situation in the scientific field, creating an artificial shortage of the youngest and most promising higher qualification personnel.

Now, let us consider the same indicators of the work of the doctoral school (Table 2). Unfortunately, the array of data in this sphere is limited to the period of 1990–2022.

Table 2. Dynamics of the number of doctoral students, admission and graduation from doctoral programs, persons

Year	Number of doctoral students at the end of the reporting year	Admission to doctoral programs in the reporting year	Graduation from doctoral programs in the reporting year		Share of graduates who defended their dissertations, %
			total	with thesis defense	
1990	1,772	n.d.	71	31	44
1991	1,834	n.d.	430	154	36
1992	1,644	540	617	247	40
1995	2,190	904	464	137	30
2000	4,213	1,637	1,251	486	39
2005	4,282	1,457	1,417	516	36
2010	4,418	1,650	1,259	336	27
2011	4,562	1,696	1,321	382	29
2012	4,554	1,632	1,371	394	29
2013	4,572	1,582	1,356	323	24
2014	3,204	166	1,359	231	17
2015	2,007	419	1,386	181	13
2016	921	397	1,346	151	11
2017	1,059	439	253	65	26
2018	1,048	393	330	82	25
2019	955	386	356	82	23
2020	979	351	339	63	19
2021	932	210	354	87	25
2022	888	340	316	77	24

Source: compiled by the author according to (Vlasova i dr., 2023a; Federal'naya sluzhba...; Obrazovanie v Rossii..., 2003; Rossiiskii statisticheskii ezhegodnik ..., 1996).

Table 2 indicates that in 2014 and 2017, there was a dramatic decrease in the number of doctoral students coming to and graduating from doctoral programs. There was also a multifold decrease in the number of defenses, although the proportion of graduates who defended their dissertations rose.

Here we observe processes similar to those in postgraduate schools with similar conclusions about a possible future shortage of higher scientific personnel in this category. Yet in this case, the staff shortage will be less noticeable, because, as demonstrated in Figure 1, the number of scientific personnel with doctoral degrees had been growing up until 2015, while the number of candidates of sciences engaged in research has been decreasing with varying speed throughout the past 30 years.

After the quantitative and qualitative assessment of the dynamics of change in personnel training in higher education, it is worth focusing on the statistics of graduation by the primary branches of science.

Analyzing data in Table 3, we can conclude that there has been no radical change in the structure of admission to and graduation from postgraduate schools from 1995 to 2022. The cumulative share of graduates of natural, medical, and technical profiles (in Table 3 these are specialties from physics and mathematics to agriculture) was 62 % in 1995. In 2022, there were the same 62.2 %. There have been no fundamental structural changes over the past 30 years in

practically all fields of study. Of note is only a slight increase in the share of law and political science graduates, as well as those in cultural and sociocultural studies.

Table 3. Dynamics of graduation from postgraduate studies in the main areas of training, persons, %

Title	Graduation from postgraduate school, persons						With thesis defense, %			
	1995	1995, %	2000	2010	2022	2022, %	1995	2000	2010	2022
Total	11,369	100	24,828	33,763	13,865	100	23	30	28	13
including by branches of science:										
physics and mathematics	1,157	10.2	1,933	1,771	1,102	7.9	15	21	25	25
chemistry	387	3.4	725	878	483	3.5	19	35	35	26
Earth sciences	402	3.5	971	1,159	536	3.9	16	21	20	8
biology	561	4.9	1,354	1,680	734	5.3	20	29	26	14
architecture	54	0.5	130	…	40	0.3	2	12	…	3
technology	3,062	26.9	6,208	7,761	3,333	24.0	17	23	25	12
medicine	947	8.3	1,730	2,798	1,628	11.7	46	52	44	11
agriculture	502	4.4	1,047	1,078	774	5.6	17	31	27	22
psychology	216	1.9	483	770	242	1.7	25	29	28	12
economics and management	993	8.7	3,807	5,887	1,133	8.2	27	36	30	9
sociology and social work	185	1.6	391	548	157	1.1	34	34	29	3
law	263	2.3	979	2,554	754	5.4	35	35	22	7
political science and regional studies	71	0.6	199	466	188	1.4	24	28	27	9
education and pedagogy	653	5.7	1,414	2,179	845	6.1	36	44	32	6
linguistics and literary studies	659	5.8	1,320	1,573	593	4.3	24	29	35	21
history and archeology	549	4.8	892	1,093	430	3.1	24	31	31	12
philosophy, ethics, and religious studies	367	3.2	607	670	215	1.6	29	32	30	7
art history	312	2.7	438	521	247	1.8	3	5	15	6
cultural studies and sociocultural projects	18	0.2	163	223	121	0.9	33	32	25	14

Source: compiled by the author according to (Vlasova i dr., 2023a; Federal'naya sluzhba...; Obrazovanie v Rossii..., 2003; Rossiiskii statisticheskii ezhegodnik..., 1996).

Let us now consider the same indicators for doctoral schools, which are provided in Table 4.

Table 4. Dynamics of graduation from doctoral studies in the main areas of training, persons, %

Title	Graduation from doctoral school, persons						With thesis defense, %			
	1995	1995, %	2000	2010	2022	2022, %	1995	2000	2010	2022
Total	464	100	1251	1259	243	100	30	39	27	23
including by branches of science:										

physics and mathematics	51	11.0	178	100	14	5.8	25	26	27	43
chemistry	12	2.6	44	38	7	2.9	50	32	24	14
Earth sciences	12	2.6	45	45	5	2.1	8	36	11	-
biology	12	2.6	36	47	9	3.7	42	22	17	11
technology	147	31.7	355	324	74	30.5	31	42	31	23
medicine	23	5.0	76	74	1	0.4	52	53	30	-
agriculture	4	0.9	14	38	4	1.6	50	57	26	50
history and archeology	26	5.6	65	46	12	4.9	19	31	22	8
philology	28	6.0	81	100	16	6.6	29	31	24	19
philosophy	28	6.0	42	49	4	1.6	36	36	39	0
art history	3	0.6	2	3	1	0.4	33	100	33	0
cultural studies	0	0.0	3	15	6	2.5	-	0	7	17
psychology	8	1.7	9	25	6	2.5	13	11	16	0
economics	...	...	...	154	45	18.5	...	...	31	27
pedagogy	21	4.5	99	125	14	5.8	5	45	22	7
sociology	9	1.9	27	28	4	1.6	11	48	21	0
law	15	3.2	20	29	21	8.6	13	45	24	29
political science	6	1.3	4	13	-	0.0	0	25	46	-

Source: compiled by the author according to (Vlasova i dr., 2023a; Federal'naya sluzhba...; Obrazovanie v Rossii..., 2003; Rossiiskii statisticheskii ezhegodnik..., 1996)

The structure of doctoral graduates by branches of science also does not show any major change between 1995 and 2022. The only thing to note is a minor decline in the share of graduates in natural sciences, medicine, and technology profiles (similarly to conclusions from Table 3) from 56 to 4 %. Nevertheless, this kind of change cannot be considered significant. Concerning specific branches of science, we can point out a decline in the number of medical graduates.

In this way, we can conclude that against the backdrop of the quantitative reduction of the number of postgraduate and doctoral graduates, there is no notable structural change across the directions of training.

5. Conclusion

Thecorrelation analysis showed that due to the high dependence of innovation processes on the availability of researchers with scientific degrees, the absence of significant changes in the innovation activity of the Russian industrial sector is primarily due to the gradual reduction of personnel – graduates of higher education.

Over the past three decades, Russia has experienced a gradual decrease in the number of researchers in the scientific sphere. The initial collapse in the first half of the 1990s was followed by a slow decline until the present time. This reduction takes place practically in all categories of researchers, except for doctors of sciences, which, on the contrary, have become noticeably more numerous in recent decades. As a consequence, the share of researchers with doctoral degrees increased 5.5-fold from 1990 to 2021.

From 1995 to 2010, there was a major (almost threefold) rise in the number of postgraduate students and doctors accompanied by a rise in the relative share of postgraduate students with defended theses. This exact period is described by many researchers as a "diploma factory" because, according to a range of authors, the scientific value of the bulk of these dissertations was not very high.

The year 2014 was marked by a dramatic drop in the number of postgraduate students and doctors. Admission to doctoral schools lowered almost by 10 times compared with 2013. Accordingly, since 2017, there was a reduction in the number of higher school graduates. In the meantime, despite considerable quantitative shifts, the structure of graduates by branches of science has not changed much since 1995.

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