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SOCIAL PROBLEMS

# Forecast of Staffing Needs for the Artificial Intelligence Sector in Russia

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**Abstract**—The article presents a science-based approach to assessing the staffing needs for the artificial intelligence sector in Russia by the analogy method. The use of the method is justified by the lack of basic indicators for the economy and the labor market of the AI sector in Russian economic statistics and other sources. The selection of a benchmark country for the transfer of the AI indicator structure to the Russian labor market was based on three factors, i.e., availability of national labor market data, similarity of the employment structure in the economy, and comparable publication activity. Based on the developed methodological approaches, quantitative indicators of the average annual number of employees for the medium-term period up to 2025, as well as indicators of additional annual staffing requirements for the first time have been created for the Russian AI sector.

**Keywords:** artificial intelligence, labor market, staffing needs forecast, analogy method

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***Introduction.*** For the Russian Federation, artificial intelligence is currently a strategically vital area in the focus of government attention [1]. Federal-level program documents[1] declare strategic goals for the development of artificial intelligence (AI) in Russia, including the promotion of welfare and quality of life of Russians, national security, competitive economy, and achieving leading positions on the global stage. The crucial task of attaining the set goals is to provide the Russian market of artificial intelligence with qualified personnel, the demand for which grows exponentially.[2]

The importance of highly skilled or highly productive personnel including the staff for AI sector for the RF economy has already been repeatedly emphasized in Russian scientific publications [2]. An insight into the volume of demand for such personnel will make it possible more actively to modernize production and introduce new technologies, carry out digitalization and automation of production, which, in turn, will promote the efficiency of labor resources management [3].

In recent years, the number of scientific studies on the impact made by artificial intelligence on the labor market has increased markedly. The article by Mottaeva et al. [4] reveals both positive (growth in labor productivity and acceleration of economic growth) and negative (job cuts and rising unemployment) consequences of using AI technologies. In their research, Xue and Filimonenko analyze the impact of artificial intelligence on China's total employment and labor force structure [5]. The authors note that the development of AI technologies creates more employment opportunities for highly skilled labor and has a negative impact on the employment of low- and medium-skilled workers. In the publication of Leksin [6] it is pointed out that the development of artificial intelligence, robotics, and other modern technologies will make fundamental changes not only in the organization of labor but also in the social structure of society. Buklemishev raises the question on the possible use of AI technologies in the Russian public sector [7].

A similar trend is observed among foreign publications. Most of the current research is aimed at studying the impact of AI technologies on the labor market [8–10]. There are also works substantiating the positive effect of labor automation [11].

[1] The National Strategy for the Development of Artificial Intelligence for the Period until 2030, approved by Decree of the President of the Russian Federation of October 10, 2019, no. 490 On the Development of Artificial Intelligence in the Russian Federation. https://www.garant.ru/products/ipo/prime/ doc/72738946/. Accessed May 24, 2022. Passport of the federal project "Artificial Intelligence" of the national program Digital Economy of the Russian Federation (Appendix no. 3 to the protocol of the Presidium of the Government Commission on Digital Development, the Use of Information Technologies to Improve the Quality of Life and the Business Environment of August 27, 2020, no. 17). https://ac.gov.ru/ uploads/_Projects/AI_otbor/Passport.pdf . Accessed May 24, 2022.

[2] The struggle for AI personnel: Difficulties in finding specialists in Russia. https://ict.moscow/news/ai-talents/. Accessed May 24, 2022.

On the other hand, there are very few studies addressing the issues of employment in the sector of artificial intelligence and staffing in this area. Aliev notes that the development of AI technologies causes an increase in demand for "creativity" and highly qualified human resources [12]. Undoubtedly, the success of achieving ambitious goals in the field of AI development will largely be determined by the extent, to which the Russian government will be able to mobilize and use the intellectual potential of the nation and, above all, adapt the education system to training qualified personnel [13]. The target guideline for determining the scope of training for such specialists should be a scientifically sound forecast of the need for personnel with AI competencies.

Foreign authors raise the issue of the need for low-paid AI personnel who perform secondary functions, such as data markup. Tubaro and Casilli, using the example of the automotive industry, show that the need for such workers is not temporary but structural, which will necessarily accompany the further development of the economy [14]. Acemoglu et al. study the impact of AI on the labor market by analyzing vacancy data in the United States; the researchers note a significant increase in the number of vacancies related to AI in 2010–2018 but conclude that there is currently no evidence of deep AI penetration into the labor market [15].

Some indicators of the Russian labor market in the sector of artificial intelligence appear in various analytical collections. Thus, in the almanac *Artificial intelligence. 2020 Index*[3] based on a comparison of information arrays of vacancies and resumes of specialists, the permanent shortage of AI specialists is estimated as at least five thousand people. Analytical report "Index of readiness of priority branches in RF economy to introduction of artificial intelligence"[4] based on to the results of a survey covering ten thousand Russian companies provides information on the average number of AI specialists in companies of various economic branches, and the conclusion is that their number in the labor market should be increased by at least 50 % in order to ease the staff shortage.

According to a study by the Association of Computer and Information Technology Enterprises, the rapid growth of the IP market (2–3 times) and the rising demand for AI technology will lead to an increase in the annual personnel demand for highly qualified IT specialists, which by 2024 will reach the value of 300000 people/year. This need includes both the ICT sector itself and all other sectors of the economy requiring IT personnel[5] and is the upper bound for assessing the staffing needs of the AI sector.

An analysis of various sources reveals that at present no specific indicators of the current number of workers in the sector of artificial intelligence are presented in the State statistical reporting, analytical digests, or scientific publications. It should be noted that this is an international problem.

In the authoritative analytical collection "AI Index Report" (2017–2022) published by Stanford University[6], information about the US labor market in the sector of artificial intelligence is presented only through the branchwise share of AI job vacancies in the total number of vacancies.

The research of the Canadian company Element AI estimates the headcount of those employed in specialized technical roles in the development of artificial intelligence products based on data collected from self-presentations of specialists in the social network LinkedIn.[7] The total number of such workers in the world as of 2020 is 477900 people, of which 39.4% (188300) are in the United States, while the share of Russian AI specialists at the global level is less than 1% (3400 people). The figure for Russia may be underestimated due to the limited access of Russian specialists to this resource.

The main method for personnel forecasting is traditionally the macroeconomic approach based on predictive estimates of economic growth rates, labor productivity, and the size of labor resources required for achieving the planned indicators [16–18]. As can be seen from the above-presented literature review, the use of macroeconomic methodology for personnel forecasting in the sector of artificial intelligence is handicapped as there are no basic indicators of the economy and the labor market specific for this area such as gross value added, investment volume, labor productivity, and number of employees by type of economic activity in Russian economic statistics, policy documents, and analytical collections.

In this connection, the research goal of the article is to adapt the personnel forecasting methodology to the sector of artificial intelligence and, on its basis, to assess the indicators of the current and prospective number of employees in the AI sector as well as the annual additional need for such personnel for the medium-term planning horizon.

***Methodology.*** In the absence of the necessary macroeconomic indicators, the current and forecast

[3] Almanac Artificial Intelligence: an analytical collection. Issue 1. Review of the Russian and World AI Market. https://aireport.ru/. Accessed May 25, 2022.

[4] Analytical report "Index of readiness of priority branches in RF economy to introduction of artificial intelligence." https://ai-index.ru/. Accessed May 25, 2022.

[5] Study "IT personnel for the digital economy in Russia." https://apkit.ru/news/it-kadry-dlya-tsifrovoy-ekonomiki-v-rossii/. Accessed May 25, 2022.

[6] THE AI INDEX REPORT. https://aiindex.stanford.edu/report/. Accessed May 25, 2022.

[7] Specialized technical roles in the development of artificial intelligence products. https://jfgagne.ai/global-ai-talent-report-2020/#anchor-10 https://ai-index.ru/. Accessed May 25, 2022.

demand of AI sphere for qualified personnel can be assessed based on the analogy method. The forecasting methodology consists in analyzing the indicators of a highly developed system (country, region, industry). Next, the identified trends and development characteristics of the studied process in a highly developed system are projected onto a less developed system.[8] The analogy method is traditionally used to predict socioeconomic processes. An example of its successful use in the field of personnel of the highest scientific qualification is presented in the article [19]. At the same time, the main drawback of the method was noted by Shirov: "the use of ready-made dependences calculated for other countries, as a rule, does not improve the quality of forecasting tools and worsens its practical value" [20].

The use of the analogy method is justified if it is impossible to apply other methods due to the lack of the necessary macroeconomic indicators. With regard to the AI sector, the analogy method involves the provision of qualified personnel in the sector of artificial intelligence in volumes and structure similar to the corresponding indicators in countries with an efficient market economy.

***Formalization of the analogy method.*** The following notation is introduced: $i$ is the type of economic activity, $t$ stands for a year; $L_i$ is the number of employees; $V_i$ is the vacancy rate; $\alpha_i^{AI}$ denotes the share of AI vacancies in the total number of vacancies in the labor market; $\gamma_i$ denotes the share of vacancies in the total staff headcount in the labor market; $\sum$ stands for value for all types of economic activity; AI is the artificial intelligence, and ICT denotes the information and communication technologies.

The number of AI vacancies in the labor market is determined by the following ratio:

$$V_i^{AI} = \alpha_i^{AI}(t) V_i^{Total}, \quad \text{where } V_i^{AI} \ll V_i^{Total}. \tag{1}$$

Since the vacancies $V_i$ are a subset of the total number of employees $L_i$ ($V_i \ll L_i$), the following equality will hold:

$$V_i = \gamma_i L_i. \tag{2}$$

Then the vacancy rate in the sector of artificial intelligence is obtained as

$$V_i^{AI} = \gamma_i L_i^{AI}; \quad V_i^{Total} = \gamma_\Sigma L_i^{Total}. \tag{3}$$

In order to find $\gamma_i$ and $\gamma_\Sigma$ we use the data on the headcount and need of organizations for employees with higher education for ICT professional group i.e.

$$\begin{cases} V_i^{ICT} = \gamma_i L_i^{ICT} \rightarrow \gamma_i = \dfrac{V_i^{ICT}}{L_i^{ICT}} \\ V_i^{Total} = \gamma_\Sigma L_i^{Total} \rightarrow \gamma_\Sigma = \dfrac{V_i^{Total}}{L_i^{Total}} \end{cases}. \tag{4}$$

By substituting (4) into (3), we obtain

$$V_i^{AI} = \frac{V_i^{ICT}}{L_i^{ICT}} L_i^{AI}; \; V_i^{Total} = \frac{V_i^{Total}}{L_i^{Total}} L_i^{Total}.$$

Since $V_i^{AI}$ and $V_i^{Total}$ are connected by the relation (1) where $\alpha_i(t)$ is a known value

$$\frac{V_i^{ICT}}{L_i^{AI}} L_i^{AI} = \alpha_i(t) \frac{V_i^{Total}}{L_i^{Total}} L_i^{Total}. \tag{5}$$

Hence $L_i^{AI}$ is obtained as follows:

$$L_i^{AI} = \alpha_i(t) \beta_i L_i^{Total}, \tag{6}$$

$$\text{where } \beta_i = \frac{V_i^{Total}/L_i^{Total}}{V_i^{ICT}/L_i^{ICT}}. \tag{7}$$

***Choice of benchmark country.*** The application of the analogy method requires selecting a reference benchmark country in order to transfer the structure of its indicators to the Russian labor market. As part of the study, the choice was made based on three factors, i.e., the availability of national data characterizing the labor market in the field of AI; similarity of employment structures; and comparative publication activity.

The benchmark country for applying the analogy method for forecasting is selected from among the countries with an available retrospective statistical base and characterized by a high development level of AI technologies. The leaders in the development and use of these technologies are the United States, China, Japan, the UK, and Germany.[9] For these countries, retrospective data are available that characterize the state of the AI sector, including labor market indicators.

In order to assess the similarity between employment structures in Russia and these countries based on the employment volume by types of economic activity, the Ryabtsev index was calculated, which is the ratio showing the actual measure of the difference between the values of the components within two structures with their maximum possible value [21]

$$I_R = \frac{\sqrt{\sum_{i=1}^{n} \left(d_i^1 - d_i^0\right)^2}}{\sqrt{\sum_{i=1}^{n} \left(d_i^1 + d_i^0\right)^2}},$$

[8] Fundamentals of social and economic forecasting. https://kpfu.ru/portal/docs/F147717178/Osnovy.socialnogo.i.ekonomicheskogo.prognozirovaniya.MAG.pdf. Accessed May 25, 2022.

[9] Artificial Intelligence Index Report 2021. Stanford University Human-Centered Artificial Intelligence, 2021, p. 222. https://aiindex.stanford.edu/ai-index-report-2021/. Accessed May 25, 2022.

where $d_i^1$, $d_i^0$ are specific weights of attributes in populations and $i$ is the number of gradations in the structures.

Calculations show that the lowest value of the Ryabtsev index (the index value is 0.014) is typical of Russia and the United States, which indicates a low level of difference between the employment structures in the economies of these countries. In addition to this, the results of the Ryabtsev index calculated for employment structures in the professional group "Managers and ICT specialists" also show that Russia and the United States have a low level of difference in employment structures for this professional group (the index value is 0.156).

In order to compare Russia's position in research in the sector of artificial intelligence, an analysis was made of the number of publications in scientific journals indexed in the international Scopus database in dynamics from 2010 to 2020. The search was carried out based on selection of the keywords "Artificial intelligence/# Iskusstvennii intellekt#" and the name of the country, with which the authors are affiliated, according to the publication analysis methodology [22] (see Table 1).

Data in Table 1 suggest that the publication activity of national authors in publications indexed in the Scopus MDB indicates a 10-year lag between Russia and the countries that are leaders in the field of AI.

To identify positions in the development of the AI sphere in these countries, the values of popular AI indices (as of 2020) were compared with the values of the indices in the retrospective period. These indices include The Global AI Index[10], AI Readiness Index[11], and Artificial Intelligence Index[12], indicators for which have been formed since 2016. The analysis of AI indices shows that the positions of countries and specific ranking values depend on the chosen methodology. However, the presented ratings allow us to draw some generalized conclusions about the detected trends. The undisputed leader in the field of AI, according to these data, is the United States. Russia in these ratings occupies positions 30, 33, and 26, respectively. The minimum time lag is estimated as four years.

Thus, the analysis of data on publication activity, economy, the labor market, and AI ratings allows us to choose the United States as a benchmark for forming the staffing needs of the Russian AI sector, taking into account the selected time lag.

***Calculation of projected staffing requirements.*** The key indicator characterizing the US AI labor market is the data on the share of vacancies in the sector of artificial intelligence in the total number of vacancies by type of economic activity. Figure 1 shows the vacancy rate for AI in the United States in 2011 and 2021[13] by types of economic activity.

For all types of economic activity, the share of vacancies in the field of AI relative to the total number of vacancies by the type of economic activity in 2011 was 0.28%, and by 2021, it increased to 0.93%. The leading types of economic activity are also changing: while in 2011 the manufacturing industry (Manufacturing) ranked first at 0.73%, by 2021, in terms of the share of vacancies in the field of AI, the leadership is intercepted by the information and communication industry (Information) with 3.3% of vacancies with AI competencies in relation to the total number of vacancies. In 2021, according to this indicator, the US manufacturing industry drops to the third place, at 2.02%, giving way to professional and scientific activities ranking second after the ICT sector, at 2.59%.

In order to confirm the validity of using the indicator, an analysis was made of the dependence between the number of vacancies and the number of employees in the respective types of economic activity, which confirmed their linear correlation. Since vacancies are announced by the employer and they involve the filling of these vacancies by workers, i.e., employees [23], the category "employees" is used in the calculations below.

[10]The Global AI Index. Tortoise Media. https://www.tortoisemedia.com/intelligence/global-ai/.

[11]AI Readiness Index 2020. https://www.oxfordinsights.com/government-ai-readiness-index-2020.

[12]2020 Global Vibrancy Ranking. https://aiindex.stanford.edu/vibrancy/.

[13]Artificial Intelligence Index Report 2021. Stanford University Human-Centered Artificial Intelligence. 2021. p. 88. https://aiindex.stanford.edu/ai-index-report-2021/.

**Table 1.** Cross-country comparisons of the number of publications on the subject of AI in journals indexed in the Scopus IDB

| Country | Number of publications | |
|---|---|---|
| | 2010 | 2020 |
| Russia | 2770 | 18678 |
| United States | 70789 | 111142 |
| Germany | 18265 | 31563 |
| Japan | 10469 | 15730 |
| UK | 20635 | 39669 |

Source. Calculation based on data from the Scopus IDB and national statistical agencies.


**Fig. 1.** Share of vacancies in the AI field in relation to the total number of vacancies in TEA, in the United States in 2011 (▨) and 2021 (⊡).
Source: Artificial Intelligence Index Report 2021.

The analysis of the items in the All-Russian classifier of types of economic activity (OKVED2)[14] and the US International Standard Industrial Classification of All Economic Activities (ISIC v.4)[15] shows that most of the types of economic activity (TEA) are similar. Analogues of TEA "Manufacturing industries," "Activities in the field of information and communication," and "Financial and insurance activities" are "Manufacturing," "Information and communication," and "Financial and insurance activities." The exception is TEA "Wholesale and retail trade; repair of motor vehicles and motorcycles," which corresponds to two branches of the US economy "Wholesale Trade" and "Retail Trade." In this case, the number of employees by TEA was recalculated based on the arithmetic weighted average where, the shares of retail and wholesale trade in the average number of employees (ANE) were used as weighting factors.

***Evaluation of model parameters.*** For the transition from the number of vacancies $V_i^{\mathrm{AI}}$ in the AI field to the ANE $L_i^{\mathrm{AI}}$, the proportionality factor $\beta_i$ was calculated from the relation (7) for each type of economic activity. The calculations used data on the payroll number of employees and the number of vacancies by professional groups in the field of ICT. Information and communication technology data can be used, as AI technologies are a subset of ICT technologies. Proportionality factor $\beta_i$ is the ratio of the share of ICT workers in the total number of employees to the share of ICT vacancies in the total number of vacancies for each type of economic activity. Table 2 shows the calculated values of this factor.

The average payroll headcount (employees of organizations without small businesses) in 2020 amounted to 26.4 million people, of which 406 100 are specialists with higher education (HE) in ICT, which is 1.5% of all employees. The calculation of the number of vacancies takes into account the places vacated in the

[14]IC 029-2014 (NACE Ed. 2). All-Russian classifier of types of economic activity (approved Order of Rosstandart dated January 31, 2014, no. 14-st) (ed. as of 23.12.2021). http://www.consultant.ru/document/cons_doc_LAW_163320/. Accessed May 25, 2022.

[15]International Standard Industrial Classification of All Economic Activities (ISIC) Rev.4 International Standard Industrial Classification of All Economic Activities (ISIC) Revision 4, UN, 2009. https://unstats.un.org/unsd/publication/SeriesM/seriesm_4rev4r.pdf . Accessed May 25, 2022.

**Table 2.** Indicators of employment in ICT sector for the calculation of the proportionality factor, 2020

| TEA code | Payroll headcount, thousand people | | Share of employees with HE in ICT in the total number of employees, % | Job vacancies, thousand | | Share of ICT job vacancies in the total number of vacancies, % | Proportionality factor |
|---|---|---|---|---|---|---|---|
| | specialists with HE in ICT | total number of employees | | for specialists with HE in ICT | total for TEA | | |
| | $L_i^{ICT}$ | $L_i^{Total}$ | $\frac{L_i^{ICT}}{L_i^{Total}}$ | $V_i^{ICT}$ | $V_i^{Total}$ | $\frac{V_i^{ICT}}{V_i^{Total}}$ | $\beta_i$ |
| | 1 | 2 | 3 = 1/2 | 4 | 5 | 6 = 4/5 | 7 = 3/6 |
| A | 3.8 | 875.7 | 0.44 | 0.3 | 41.66 | 0.64 | 0.68 |
| B | 6.8 | 928.7 | 0.73 | 0.1 | 22.51 | 0.61 | 1.2 |
| C | 50.2 | 4742.2 | 1.06 | 1.5 | 140.11 | 1.07 | 0.99 |
| D | 15.6 | 1280.3 | 1.22 | 0.5 | 48.34 | 0.95 | 1.28 |
| E | 2.2 | 331.8 | 0.65 | 0.1 | 13.01 | 0.75 | 0.87 |
| F | 7.0 | 864.8 | 0.81 | 0.2 | 51.26 | 0.37 | 2.21 |
| G | 29.2 | 2432.4 | 1.20 | 1.6 | 148.01 | 1.09 | 1.1 |
| H | 17.7 | 2337.8 | 0.75 | 0.7 | 115.62 | 0.62 | 1.21 |
| I | 1.1 | 282.1 | 0.38 | 0.1 | 17.81 | 0.35 | 1.08 |
| J | 164.3 | 774.4 | 21.21 | 7.3 | 31.47 | 23.14 | 0.92 |
| L | 8.1 | 433.4 | 1.86 | 0.3 | 31.66 | 0.89 | 2.09 |
| M | 46.7 | 1328.5 | 3.52 | 1.8 | 50.15 | 3.64 | 0.97 |
| N | 4.1 | 601.9 | 0.68 | 0.3 | 36.46 | 0.74 | 0.92 |
| P | 22.2 | 4828.2 | 0.46 | 0.6 | 80.56 | 0.76 | 0.6 |
| Q | 21.1 | 3725.9 | 0.57 | 0.8 | 183.24 | 0.42 | 1.36 |
| R | 6.2 | 677.1 | 0.92 | 0.2 | 17.9 | 1.29 | 0.71 |
| Total | 406.1 | 26445.2 | 1.54 | 16.3 | 1029.75 | 1.58 | 0.97 |

Source. Form of federal statistical observation 1-T (prof.), the authors' own calculations.

event of the dismissal of employees, going on maternity leave or parental leave, as well as newly created ones. Total number of vacancies for all types of economic activity amounted to 1.02 million and the share of specialists with HE in the field of ICT is 1.6%, or 16300 people.

The resulting average proportionality factor ($\beta_i$ = 0.97) is close to one, therefore, the share of vacancies in the field of ICT in the total number of vacancies coincides with the share of ICT workers in the total number of employees. At the same time, the maximum value of the coefficient ($\beta_i$) in the construction industry is 2.21, and the minimum is in the field of education and is equal to 0.6.

The assessment of the lag between the Russian and American AI sectors was refined taking into account the difference in the level of AI implementation in certain types of economic activity. The level of AI adoption in each TEA was assessed based on the number of scientific publications on that type of economic activity. The use of this approach is based on the assumption that the more scientific publications in a particular industry and country, the higher the level of implementation of AI technologies, and the greater the volume of AI products. In order to determine the level of AI development for each TEA, we analyzed the quantitative value of the number of scientific articles indexed in the Scopus IDB for 2020, published by AI product developers in the United States and Russia. In total, 65200 publications in the United States, and 13200 publications in Russia were identified in the Scopus IDB on AI. Articles were assigned to a particular type of economic activity based on a list of keywords, which included the name of the country, with which the authors of the scientific publication were affiliated, particular types of economic activity, and AI technology areas. The algorithm for identifying areas of AI technologies is presented in a separate article [24].

Table 3 shows data on the number of publications for Russia and the United States in the context of TEA, summed over AI technology areas, as well as the calculated time lag in the development of the AI sector in these countries by TEA.


**Fig. 2.** Share of AI vacancies in the total number of vacancies with allowance for the time lag: ▤ 2011, lag of 10 years; ⬚ 2013, lag of 8 years; ▩ 2015, lag of 6 years; ▨ 2017, lag of 4 years.
Source. Aggregated data of Artificial Intelligence Index Report, 2021.

It should separately be noted that different algorithms for forming a sample of publications result in different integral values of the publications number (Tables 1, 3).

Through expert analysis of the presented values, a time lag was determined that qualitatively reflects the difference between countries for individual TEAs – a lag of 4, 6, 8 or 10 years. For the maximum value of the share of RF publications in relation to the United States, a lag of four years was chosen, which was determined by AI indices. The maximum lag of ten years was chosen based on a general comparison of publication activity. Intermediate values of six and eight years were determined by grouping indicators. Differences in the proportion of AI job vacancies depending on the selected time lag are reflected through the coefficient $\alpha_i(t)$ and are presented in Fig. 2.

In most types of economic activity, a decrease in the time lag leads to an increase in the share of vacancies in the AI field. Thus, for example, when the lag changed from ten to four years for TEA "J—Activities in the field of information and communication," the share of AI vacancies in relation to the total number of vacancies increased from 0.58 to 1.9%; while on reducing the lag for TEA "M—Professional, scientific and technical activities" to six years, the share of AI job vacancies increased from 0.57 to 1.09%; when the lag is reduced to eight years in TEA "K—Financial and insurance activities" the rise was from 0.22 to 0.27%.

***Estimated indicators of staffing needs.*** Taking into account the calculated proportionality factor based on the structure of AI vacancies by types of economic activity in the United States, the selected time lag for TEA as well as the number of employees in Russia by types of economic activity in 2020, the indicators of Russia's staff headcount with AI competencies were developed for 2021.

The calculation for each TEA was based on relation (6). In developing forecasts indicators for 2025, the number of employees in Russia by types of economic activity was calculated based on retrospective (2010–2021) dynamics of the structure of TEA and the projected population size[16].

Forecast values of the AI staff headcount in Russia in 2021 and 2025 calculated from this relation are shown in Fig. 3.

Over four years, the order of the top four leading TEAs has not changed, both in 2021 and 2025, in terms of the number of AI employees, TEA "C—Manufacturing industries" is in first place with 57400 and 117500 employees, respectively. The second and third places are occupied by TEA "M—Professional, scientific and technical activities" with the number of employees 21900/48100 people and TEA "J—Activities in the field of information and communication" with the number of AI employees amounting to 20600/35600 people. The fourth place is taken by TEA "O—Governance and military security; social security" with 17600/27700 thousand people. Among the TEA with decreased AI staff headcount there are "G—Wholesale and retail trade" where the number of AI employees dropped from 11000 people to 10800 people, and "B—Mining" with a drop from 8800 down to 8300 employees. The multiple increases in the number of AI employees are observed in TEA "K—Financial and insurance activities," "D—Provision of electrical energy, gas and steam; air conditioning" and "L—Real estate activities."

At the same time, the number of AI employees in the financial sector is estimated as 2700 people in 2021 and 7900 in 2025, and this may be an underestimate.

[16]Estimated population of the Russian Federation until 2035/Rosstat.https://rosstat.gov.ru/compendium/document/-13285.

**Table 3.** Publication activity of Russian and US scientists in 2020, IDB Scopus

| TEA code | Number of publications, thousand | | The ratio of the number of publications in Russia to the United States, % | Time lag |
|---|---|---|---|---|
| | United States | Russia | | |
| B | 2827 | 1270 | 44.92 | 4 |
| J | 10 | 4 | 40.00 | 4 |
| C | 2299 | 668 | 29.06 | 6 |
| O | 903 | 240 | 26.58 | 6 |
| M | 16 201 | 4050 | 25.00 | 6 |
| E | 346 | 86 | 24.86 | 6 |
| A | 2206 | 547 | 24.80 | 6 |
| U | 386 | 92 | 23.83 | 6 |
| F | 5203 | 1182 | 22.72 | 6 |
| R | 5077 | 999 | 19.68 | 8 |
| P | 8627 | 1564 | 18.13 | 8 |
| N | 6910 | 1211 | 17.53 | 8 |
| D | 638 | 100 | 15.67 | 8 |
| H | 3625 | 540 | 14.90 | 8 |
| K | 996 | 141 | 14.16 | 8 |
| S | 892 | 105 | 11.77 | 10 |
| G | 86 | 10 | 11.63 | 10 |
| I | 114 | 12 | 10.53 | 10 |
| L | 37 | 3 | 8.11 | 10 |
| Q | 7826 | 404 | 5.16 | 10 |
| Total for all TEA | 65209 | 13228 | 20.29 | |

Source. The authors' calculations.

According to the analytical report "Index of readiness of priority branches in the RF economy to the introduction of artificial intelligence"[17], the Russian economy sector "Financial services," which includes TEA "K—Financial and insurance activities," ranks first in terms of business readiness to implement AI technologies, with 56.8% of companies in the industry already using them. Since at this stage, in the methodology for calculating the average number of AI employees, the time lag was determined by the number of publications, it can be assumed that the number of Russian publications in the AI field on TEA "K—Financial and insurance activities" indexed in the Scopus IDB, does not reflect the real position in the industry.

Based on our calculations, the total number of AI employees in Russia in 2021 was 182900 people. In order to determine the annual growth, the forecast value of Russia's number of AI employees was similarly calculated for 2022–2025, inclusive. For 2022, the forecast number of employees was 202 800 people, for 2023 it is 242100, for 2024 it is 291800, and for 2025, it is 323900 people.

Averaged over five years, the increase in the average annual number of employees is 35200 people, which signifies the annual additional staffing requirement (ASR) in the sector of artificial intelligence. It should be noted that the calculated ASR consists of two components: the need associated with the creation of new jobs resulting from the implementation of investment projects and the emergence of new industries as well as requirements arising in connection with a change in the volume of production of goods and services during the modernization of existing ones [18]. The third component setting off of the natural age attrition for the sector of artificial intelligence is not taken into account because AI employees are mostly classified as young people; according to hh.ru research and MADE Academy of Big Data from Mail.ru, the average age of Russian data science specialists is 25–34 years.[18] Similar age trends are observed in the largest foreign IT companies: for Facebook, the median age of employ-

[17]Analytical report "Index of readiness of priority branches in the RF economy to the introduction of artificial intelligence." https://ai-index.ru/. Accessed May 25, 2022.

[18]Portrait of a Data Scientist in Russia. Only the facts / Habr. https://habr.com/ru/company/hh/blog/467281/. Accessed September 12, 2022.

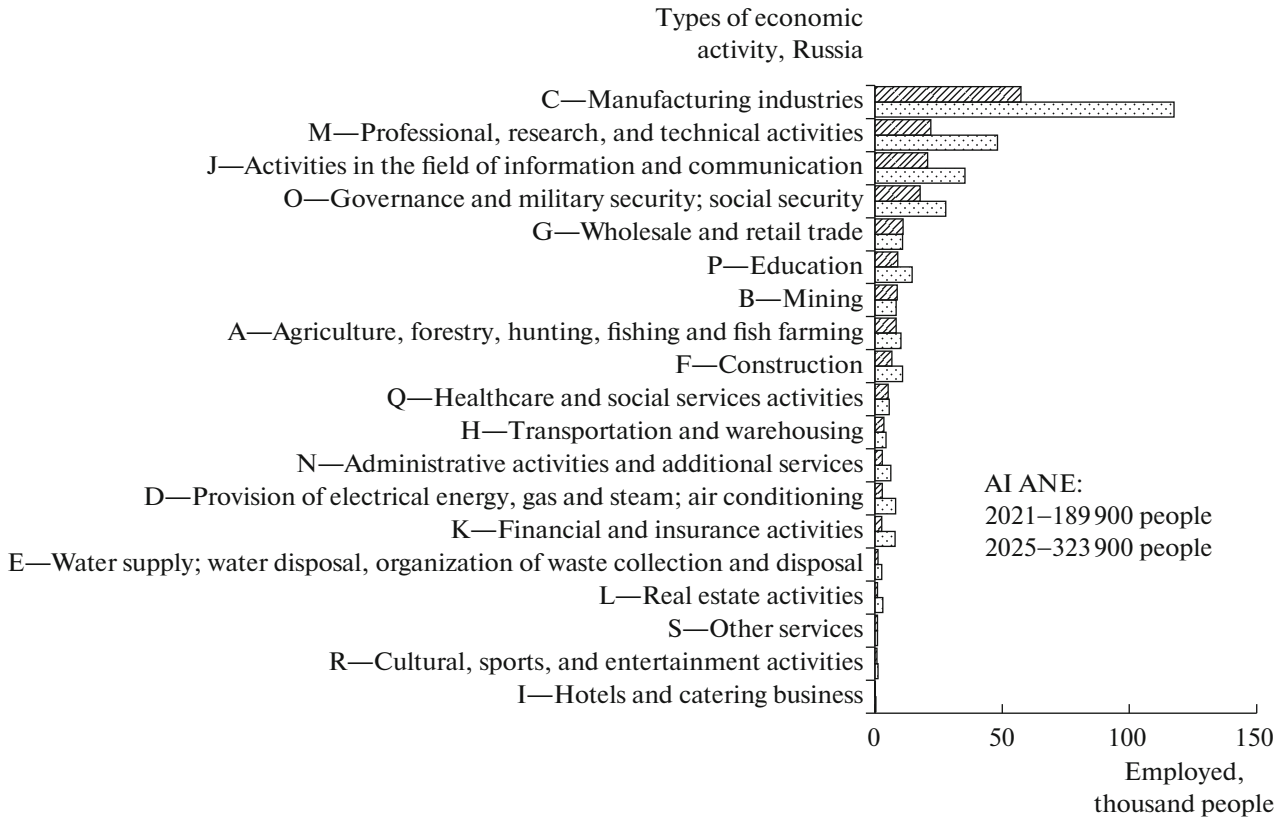


**Fig. 3.** Estimated number of foreign economic activity employees with competencies in the field of AI, Russia, 2021 (▨) and 2025 г (⬚): Source: the authors' calculations.

ees is 29 years, for Tesla 30 years, and for Apple 31 years.[19]

***Conclusions.*** The development and formalization of the methodology for calculating predictive indicators of staffing needs based on the analogy method made it possible to form quantitative indicators for the average annual number of employees for the medium term until 2025 for the Russian AI sector as well as estimates on the annual additional staffing needs in the amount of 35200 people. Such a calculation was performed for the first time and is an important guideline for the system of training and retraining of personnel with competencies in the sector of artificial intelligence. Detailed indicators of average number of employees (ANE) and ASR by types of economic activity will serve as a starting point for universities in the development of educational programs that provide graduates with competencies required by employers taking into account the specifics of industries.

One of the limitations of the developed model is the need for an expert assessment of the time lag by types of economic activity with allowance for the differences between the development levels of the compared objects.

The development of a monitoring system for the Russian labor market in the AI field, in particular, the results of the "Index of readiness of priority branches in RF economy to introduction of artificial intelligence" will make it possible to adjust the methodology and values of the indicators used in ANE and ASR calculations. With allowance for this, the annual additional staffing requirement in the AI field could take into account the outflow of AI professionals abroad, as well as the natural attrition rates.

Indicators of the volume of the technology market and gross domestic product appear promising for assessing and adjusting the value of the average annual number of employees in the AI sector, and the amount of investment in the field of AI seems feasible for estimating the annual additional staffing needs.

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[19]Top tech companies compared/Payscale. https://www.payscale.com/data-packages/top-tech-companies-compared/tech-salaries. Accessed September 12, 2022.

cussions on the subject of personnel forecasting in the AI sector.

## CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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