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LABOR AND EMPLOYMENT

A New Method for Forecasting the Staffing Needs of the Economy, Taking into Account Age and Gender Characteristics of Employment

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Abstract—The article is a continuation of a series of publications by the authors on the topic of forecasting personnel needs taking into account the age and gender structure and the number of employees. The authors propose a new method for calculating forecast indicators of total and replacement personnel needs, based on the use of employment level profiles by one-year age categories. Employment level profiles are formed using indicators of the number of employed people by one-year age categories and gender factor, obtained from the results of processing and analysis of microdata from a sample survey of the labor force. The authors developed an algorithm for implementing a new method for calculating forecast indicators of general and replacement personnel needs; the proposed algorithm was tested using the example of the Republic of Karelia.

Keywords: personnel needs, number of employees, employment level, mathematical modeling, forecasting

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INTRODUCTION

The imbalance of supply and demand in the labor market is a pressing problem for the Russian economy and has not lost its severity for several decades [1]. Today, the problem of personnel shortages has entered another phase of exacerbation, which creates risks for Russia's sustainable economic growth [2, 3]. In order to preserve the personnel sovereignty of the Russian economy, the national project "Personnel" will be implemented from 2025, the key activity of which is the formation and annual updating of a forecast of the needs of economic sectors for personnel for a five-year period.[1]

The issue of forming indicators of the economy's personnel needs has previously been relevant in our country. In the modern history of Russia, the problem of personnel planning for the training of specialists was first identified in the list of instructions of the President of the Russian Federation in 2005.[2] Then, as now, the importance of these issues was predetermined by the development of negative demographic trends, "turning labor into one of the scarcest resources in Russia" [4]. The first scientific publications on the development of a methodology for forecasting personnel needs of the economy appeared in 2003. In the article by Gurtov, Mezentsev and Pitukhin[3] the basic principles and approaches to the creation of a macroeconomic forecasting methodology developed by the Center for Budget Monitoring of Petrozavodsk State University (hereinafter referred to as the methodology of the Center for Budget Monitoring of PetrSU) were described. These approaches were then developed by the authors in monographs[4] and a number of publications.[5] Vasilyeva and Filimonenko detailed the macroeconomic methodology down to the level of municipal clusters [5]; Kosorukov proposed using the wage fund when calculating the projected number of employees [6]. The works of Kor-

[1] National project "Personnel." Government of Russia: official website. http://government.ru/rugovclassifier/916/about/.

[2] List of instructions of the President of the Russian Federation following the meeting of the Council under the President of the Russian Federation for Science, Technology and Education on October 25, 2005, No. PR-2065 of December 10, 2005. http://www.pitanie2007.ru/downloads/documents/president_1.pdf.

[3] Gurtov V.A., Mezentsev A.G., Pitukhin E.A. Modeling the needs of the regional economy for graduates of the higher professional education system // Regionology. 2003. No. 1–2. pp. 262–267.

[4] Vasiliev V.N., Gurtov V.A., Pitukhin E.A., Serova L.M., Sigova S.V., Rudakov M.N., Surovov M.V. The labor market and the educational services market in the constituent entities of the Russian Federation. M., Technosphere. 2006. 669 pp.; Pitukhin E.A., Gurtov V.A. Mathematical modeling of dynamic processes in the system "economy—labor market—vocational education." St. Petersburg, Publishing house of St. Petersburg State University. 2006. 346 pp.

[5] Gurtov V.A., Pitukhin E.A., Serova L.M. Modeling the economy's needs for personnel with professional education // Problemy Prognozirovaniya. 2007. No. 6. pp. 91–109; Gurtov V.A., Pitukhin E.A., Serova L.M., Sigova S.V. Forecasting the dynamics of demand in the labor market at various phases of the development of crisis processes in the Russian economy // Problemy Prognozirovaniya. 2010. No. 2. pp. 84–97.

ovkin [7, 8] are also devoted to solving the problems of forecasting the dynamics of employment and the labor market based on a system of factor dynamic models of vacancies and potential employees. Methodological approaches to forecasting employment and economic activity of the population based on factor extrapolation and econometric models are presented in the works of Kuznetsova et al. [9, 10]. Scenarios for assessing the prospective personnel needs of the economy based on demographic and macroeconomic forecasts are given in the work of Kashepov [11].

A new round of government attention to personnel forecasting issues occurred in 2023 following the corresponding instructions of the President of the Russian Federation.[6] In order to fulfill these instructions, the scientific team of the Federal State Budgetary Institution "All-Russian Research Institute of Labor" of the Ministry of Labor of Russia, together with representatives of government agencies, developed and for the first time approved at the highest level a Methodology for the formation of a forecast of the Russian Federation's economic needs for personnel[7] (hereinafter referred to as the federal methodology). The main provisions of the federal methodology coincide with the macroeconomic methodology of the Central Bank of PetrSU and are based on key indicators of economic development—gross regional product and labor productivity [12].

Methodologically, the annual replacement personnel requirement includes three components: to compensate for natural attrition due to age (hereinafter referred to as ANOR); to ensure growth or decline in the number of employees due to changes in production volumes; to provide new jobs during the implementation of investment projects.[8] The main volume of replacement personnel needs is due to the outflow of employees from the labor market due to natural age-related reasons, which requires a quantitative assessment of the share of this outflow. The share of workers who left the labor market (the EBB coefficient) depends on the sector of the economy, as well as on the age structure of those employed in this sector. Traditionally, this coefficient was estimated on the basis of statistical data on the number of working pensioners and adjusted using the results of a questionnaire survey of employers [13]. It is important to distinguish the EBB coefficient from simple staff turnover, which is caused by a wider range of reasons [14].

Since 2024, within the framework of the federal methodology, for the first time, the calculated indicators of attrition (outflow) of employed people began to be based on data from a sample survey of the labor force on the age and sex structure of employment. However, the sample coverage of the survey did not allow for the formation of a quantitative estimate of the EBB over the medium- and long-term forecasting horizons.

To eliminate this shortcoming, the authors in one of their recent articles [15] developed two mathematical methods for reconstructing the indicators of the annual number of employed people, taking into account the age and sex structure, from the indicators of a sample survey of the labor force. This made it possible to obtain employment characteristics by gender and age; to track the dynamics of changes in the number of employed people in younger age cohorts and the impact of pension reform on the number of employed people in older ages. At the same time, the indicators of the number of employed people by one-year age categories, reconstructed by both methods, retained their "jumpiness" and did not allow for the correct calculation of the outflow of employed people and, thus, the determination of the EBB coefficients.

To fill this gap, the authors in this article used an alternative mathematical tool for reconstructing the indicators of the number of people employed in the economy by one-year age categories. Taken together, this represents a new method for determining forecast indicators of total and replacement personnel needs. The novelty of the method, in contrast to traditional approaches to forecasting personnel needs, lies both in the use of new data sources and in the newly obtained ability to calculate the outflow of employees in each age group and to form forecast indicators of the total and replacement personnel needs by one-year age categories.

Before we begin to describe the developed method, we would like to clarify that the study addressed an expert-type problem [16]. The solution to an expert problem ("as is") is the prediction of the behavior of the object under study while maintaining current trends and external influences. For example, what is the expected number of people employed in the economy by 2030 and the outflow of employment, assuming the trends of key determining factors continue: demographic (including migration); labor market (age and gender levels of employment); and social (the transition period of the pension reform). Within the framework of this work, the construction of an expert model for forecasting the number of employed people was carried out under the assumption that the current forecast background will be maintained.

[6] Item 1 of the list of instructions of the President of the Russian Federation following the extended meeting of the Presidium of the State Council of the Russian Federation dated November 1, 2023, No. Pr-2192GS. Subparagraph "z" of paragraph 1 of the list of instructions of the President of the Russian Federation dated August 16, 2023, No. Pr-1619 following the results of the XXVI St. Petersburg International Economic Forum.

[7] Order of the Government of the Russian Federation of September 11, 2024, No. 2461-r On Approval of the Methodology for Forming a Forecast of the Russian Federation Economy's need for Personnel.

[8] Efimov I.P., Gurtov V.A., Stepus' I.S. Personnel needs of the Russian Arctic economy—a look into the future // Voprosy ekonomiki. 2022. No. 8. p. 118–132. DOI: 10.32609/0042-8736-2022-8-118-132

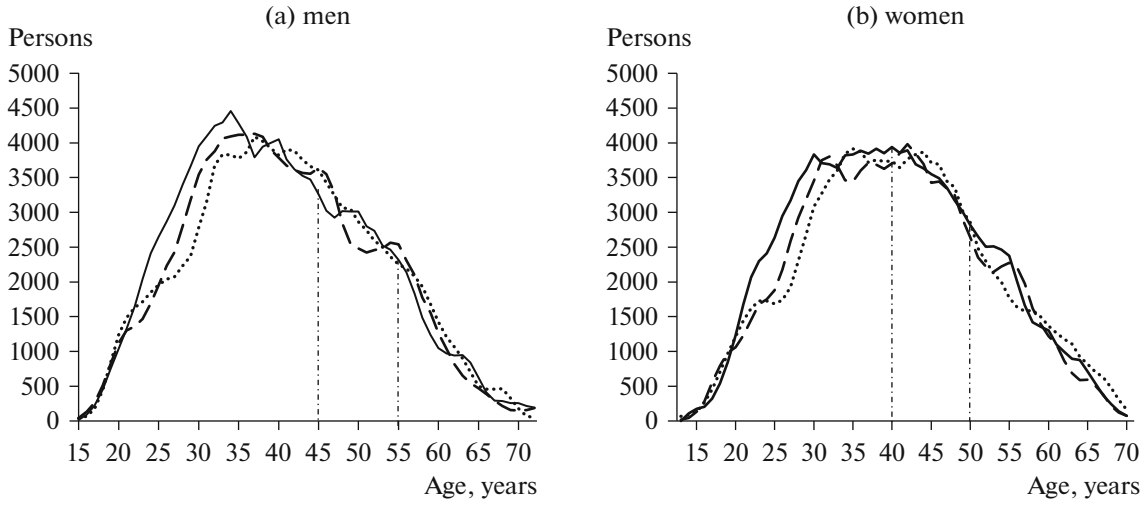

Fig. 1. Number of employed persons aged 15 to 72 years, retrospective 2019–2023: — 2019; - - - 2021; · · · 2023. Source: authors' calculations.

MATERIALS AND METHODS

The input parameters used were profiles of the number of employed people by one-year age and gender categories, formed on the basis of microdata from sample surveys of the labor force[9] and smoothed using the author's method [15]. The reconstruction of the annual number of employed persons, taking into account the age and sex structure, from the indicators of the sample labor force survey was carried out using the double smoothing method (DMA_3 with a centered moving average) of the labor force survey microdata.

The indicators of the permanent population size by annual age and sex categories for the retrospective period were formed on the basis of demographic statistics. The predicted values of these indicators were calculated based on the modified Leslie model or the age shift method with an assessment of the survival rate in the retrospective period [17].

To test a new method for forecasting the number of employed people by one-year age categories, taking into account the age and sex structure of the population, data were used for the Republic of Karelia, which is often a model region in the analysis of demographic and labor market indicators [15, 18].

The projected number of employed people, obtained by summing up by one-year age categories, is the overall personnel requirement of the regional economy. The total change in this need as the difference in the number of employed between the current and the following year (age outflows) is the replacement personnel need of the economy. An additional feature of the new forecasting method is the detailing of the total and replacement personnel requirements by one-year age categories and the gender of those employed.

Further, all data and calculations are provided for the Republic of Karelia.

Figures 1 and 2 show the number of employed people and the number of permanent population reconstructed from the results of a sample survey of the labor force, based on statistical data, using men and women in the Republic of Karelia as an example.

The availability of indicators of the number of employed and the number of permanent population by annual age categories makes it possible to form the share of employed (employment rate) in the number of permanent population by annual age categories.

THE LEVEL OF EMPLOYMENT IN THE ECONOMY

The value of the employment rate by annual age for the retrospective period from 2019 to 2023 and the average value for these years separately for men and women are shown in Fig. 3.

The employment rate value greater than one for certain age categories among men is due to the presence of interregional labor migrants in these age categories, who are included in the number of workers, but are not included in the permanent population.

Despite the different functional types of the number of employed and the number of permanent population of men and women, the employment levels of men and women show similar functional dependencies on the age of those employed in the economy.

[9] On Approval of the Main Methodological and Organizational Provisions for Conducting a Sample Survey of the Labor Force: order of Rosstat dated December 29, 2023 No. 707 (as amended on November 13, 2024). Legal reference system "ConsultantPlus." https://www.consultant.ru/document/cons_doc_LAW_467194/.

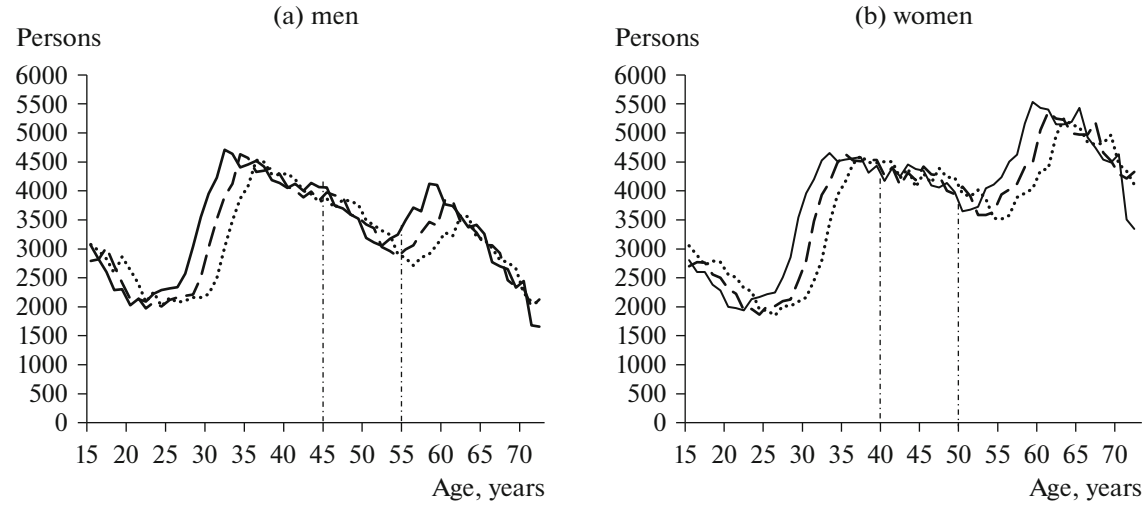

Fig. 2. Resident population aged 15 to 72 years, retrospective 2019–2023: — 2019; - - - 2021; · · · 2023. Source: data from the Federal State Statistics Service.

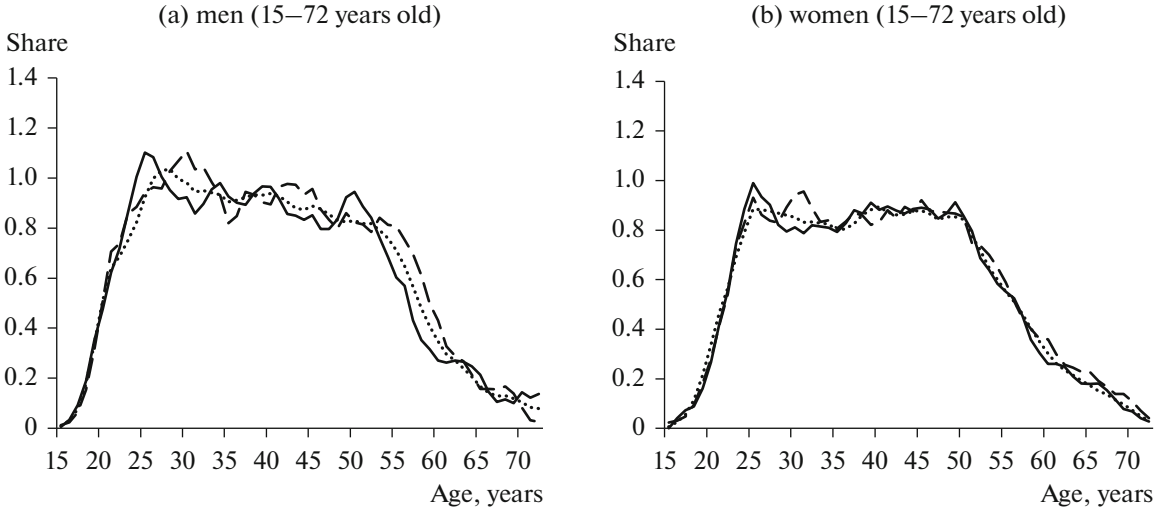

Fig. 3. Employment rate in the economy, 2019, 2023 and average for the period 2019–2023: — 2019; - - - 2023; · · · average. Source: authors' calculations.

FORECAST OF EMPLOYMENT LEVELS

Using employment level indicators for the retrospective period, taking into account the movement of the retirement age in the forecast period of 2024–2028, the following values of employment levels were obtained by annual age categories for men and women aged 55–70 and 50–65 years, respectively (Fig. 4).

Taking into account the dynamics of the employment level, we obtain profiles of employment levels for men and women by annual age categories over the forecast period (Fig. 5).

The population forecast for the future was formed using the standard age shift method taking into account the survival rate [19].

By multiplying the population by the employment level in the latest actual year 2023, we obtain the projected number of people employed in the economy on the planning horizon up to 2030 (Fig. 6).

When calculating the outflow of employed people from the indicators of the number of employed people, a jump-like curve was obtained (for both men and women). The use of various options for smoothing the number of employed people did not allow eliminating this discontinuity [15]. To eliminate this, a method of

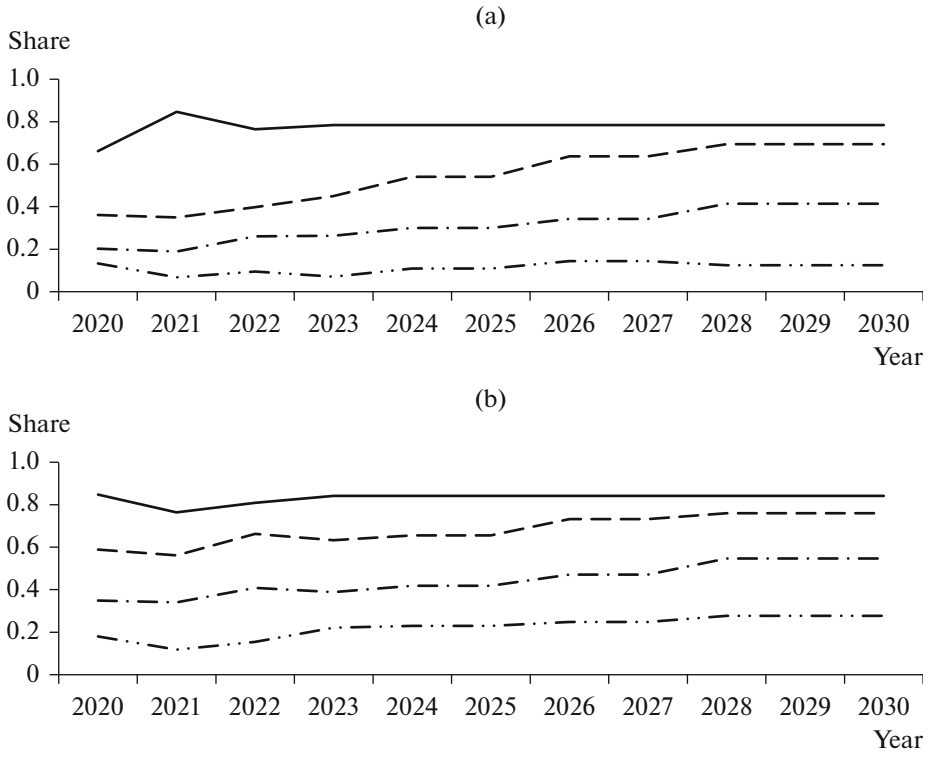

Fig. 4. Fig. 4a. Actual (2020–2023) and projected (2024–2030) employment rates for men aged 55–70: — 55 years old; - - - 60 years old; - · - · - 63 years old; - · · · - · · - 70 years old. Source: authors' calculations. Fig. 4b. Actual (2020–2023) and projected (2024–2030) employment rates for women aged 50–65: — 50 years; - - - 54 years old; - · - · - 59 years old; - · · - · · - 65 years old. Source: authors' calculations.

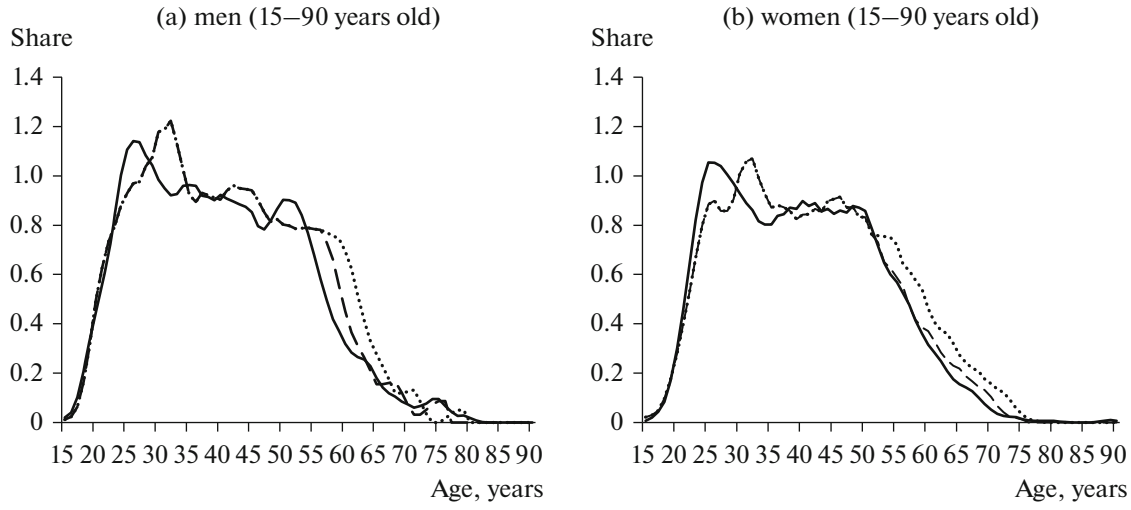

Fig. 5. Employment level profiles by annual age categories for the actual (average for 2017–2019; 2023) and forecast (2028) periods: — 2017–2019; - - - 2023; · · · 2028. Source: authors' calculations.

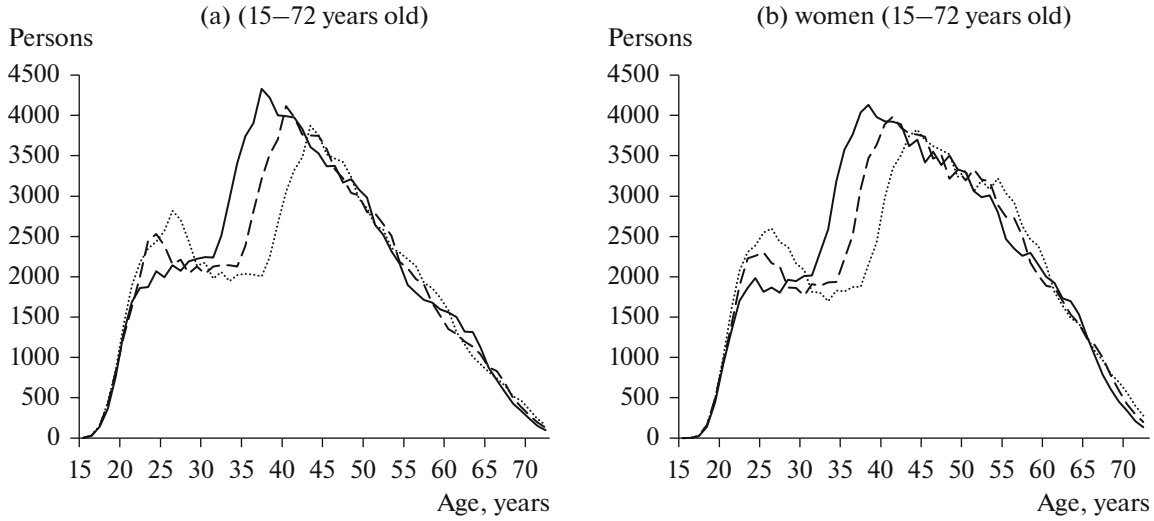

Fig. 6. Projected indicators of the number of people employed in the economy, 2024, 2027, 2030: — 2024; - - - 2027; · · · 2030. Source: authors' calculations.

replacing the real employment level function with a model function was subsequently used.

MODEL FUNCTION OF EMPLOYMENT LEVELS

Let us consider the problem of analyzing the form of the functional dependence of employment levels in the economy by annual ages in order to determine the theoretical law of distribution of a random variable describing such behavior.

The graphs in Figs. 3 and 5 for employment rates by age show a continuous function that initially increases rapidly, then maintains values over a long interval, and then declines, forming a curve resembling a bell with a flat top. In this case, the function has an asymmetric shape and gradually decreases, demonstrating asymptotic behavior, that is, it does not cross the horizontal axis. Such functions, which have the form of curves with a flat top, are known as super-Gaussian functions and belong to the "flat-top" class of Gaussian distributions,[10] when the content of the exponent of the Gaussian function is additionally raised to the power $p, (p > 1)$:

$$g(x;\mu,\sigma,p) = \frac{1}{\sigma\sqrt{2\pi}}\exp\left(-\left(\frac{(x-\mu)^2}{\sigma^2}\right)^p\right), \quad p > 1. \quad (1)$$

Moreover, the larger the value of the parameter p, the flatter the shape of the "roof" of the distribution density function becomes.

Although the flattened bell curves are well described by the super-Gaussian function, they are symmetrical. To make it asymmetric, one can choose the lognormal distribution, which is also well suited in this case due to the positive domain of the argument. $x, (x > 0)$, which is age.

A common approach to controlling the shape of the mean of the distribution density is to use a power-law modification x^α. Power exponent α controls the asymmetry of the distribution density function: for the value of the parameter $\alpha = 1$ the flat top of the distribution curve has a horizontal appearance, when $\alpha > 1$ the top of the curve grows linearly, when $\alpha < 1$ the top of the curve decreases linearly.

We apply the lognormal distribution law to (1) and introduce an additional parameter in the form of a multiplier x^α:

$$g(x;\mu,\sigma,p,\alpha) = \frac{1}{x\sigma\sqrt{2\pi}}\exp\left(-\left(\frac{(\ln x-\mu)^2}{\sigma^2}\right)^p\right)x^\alpha, \quad (2)$$
$$0 < x \langle \infty, p \rangle 1.$$

In practice, due to the age limit, in the limiting case the distribution density of the share of employed is a truncated random variable in the interval from 1 to 90 years, so that $a \le x \le b$, $a = 1$, $b = 90$.

Due to the properties of the truncated distribution, Eq. (2) may not integrate to unity over the interval $a \le x \le b$, so a normalization constant Z is required to ensure that this is a valid probability density function:

[10] Flat-top Gaussian distributions. https://math.stackexchange.com/questions/3800219/flat-top-gaussian-distributions.

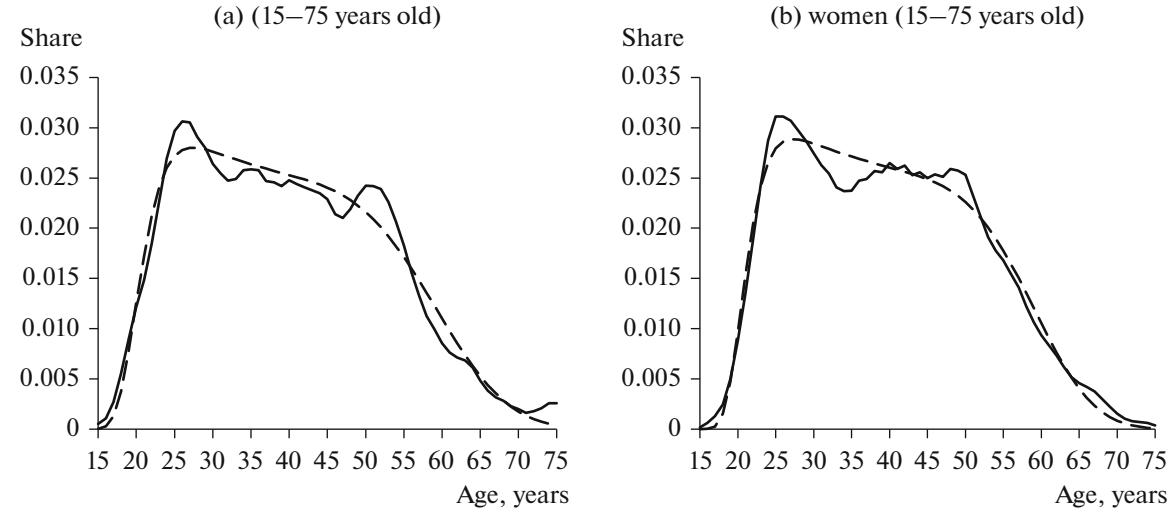

Fig. 7. Approximation of the empirical distribution density of the share of employed people (average for 2017–2019) by the model function (3): — empirical distribution density; **- - -** model function. Source: authors' calculations.

$$g(x;\mu,\sigma,p,\alpha) = \frac{1}{Z}\left[\frac{1}{x\sigma\sqrt{2\pi}}\exp\left(-\left(\frac{(\ln x-\mu)^2}{\sigma^2}\right)^p\right)x^\alpha\right], \quad (3)$$
$$a \le x \le b, \quad p > 1,$$

where Z is the normalization constant:

$$Z = \int_a^b \frac{1}{x\sigma\sqrt{2\pi}}\exp\left(-\left(\frac{(\ln x-\mu)^2}{\sigma^2}\right)^p\right)x^\alpha dx. \quad (4)$$

As a result, we obtain a four-parameter superlognormal distribution function with a power modification, expressed by Eq. (3), which we will use to describe the distribution of employment levels by age.

Figure 7 shows the functional dependences of the probability density of a random variable, calculated using relation (3) depending on ages in the range from 15 to 75 years. This curve, which describes the levels of employment of the labor force, has three distinct areas.

1. The growth of the function at younger ages from 15 to 25 years, with the growth rate determined by the parameters of the lognormal distribution μ and σ.

2. The plateau in functions in active working ages from 26 to 50 years. Parameter α determines the slope of the plateau. For values of α greater than one, the derivative of the function is positive, and the proportion of employed increases with age. For values of α less than one, the derivative of the function is negative, and the proportion of employed people decreases with increasing age. Parameter p affects the width of the plateau: when $p = 1$ there is no plateau; with increase $p > 1$ the width of the plateau increases and the steepness of the lateral regions of the distribution density function increases. Parameter μ determines the position on the abscissa axis of the mean value of the distribution density function, $\exp(\mu)$ corresponds to the average age of employed people, the parameter σ determines the dispersion of the distribution density function.

3. A decline in function in older ages from 51 to 75 years, with the rate of decline being determined by the parameters of the lognormal distribution μ and σ.

An example of approximation by function (3) of the empirical distribution density of the share of employed persons of both male and female sexes in the Republic of Karelia is presented in Fig. 7. The empirical distribution density of the share of employed people was chosen as the average over three years (2017–2019).

The selection of the parameters of function (3) was carried out using the generalized reduced gradient method [20], which is used to solve nonlinear optimization problems with constraints.[11]

The areas under the curves in Figs. 7a and 7b of the employment statistics are normalized to unity to conform to the distribution law of a random variable. To return to the original employment levels, the values of the model function are multiplied by a normalization factor.

[11] Estimates of the parameters of function (3), approximating the actual data, for men: $\mu = 3.559$, $\sigma = 0.574$, $p = 2.493$, $\alpha = 0.690$; for women: $\mu = 3.566$, $\sigma = 0.553$, $p = 2.795$, $\alpha = 0.692$. In both cases, the empirical data are well described by the model function. The approximation quality indicators are: for the proportion of male employees (Fig. 7a), the average error MAPE = 11.2%, the determination coefficient $R^2 = 0.984$; for the proportion of female employees (Fig. 7b) MAPE = 12.6%, determination coefficient $R^2 = 0.989$.

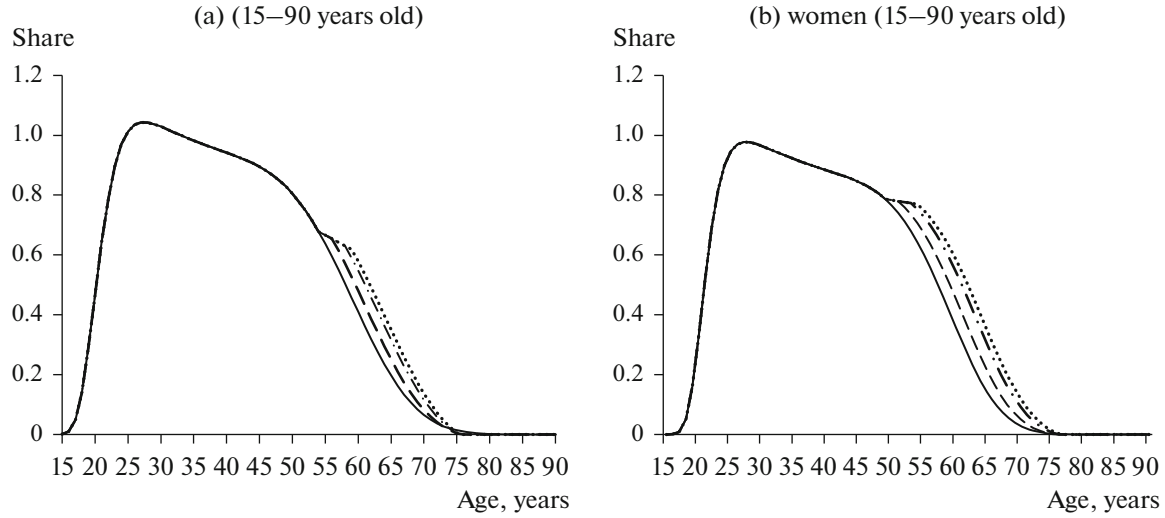

Fig. 8. Actual and projected employment levels, 2019, 2022, 2026–2027, 2030: — 2019; - - - 2022; - · - · - 2026-2027; · · · 2030. Source: authors' calculations.

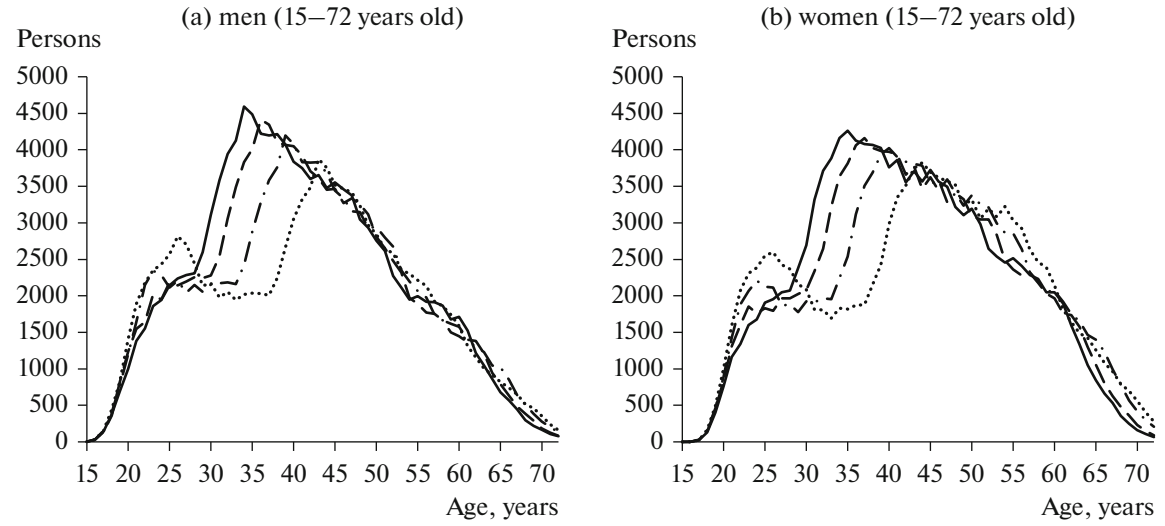

Fig. 9. Actual and projected values of the number of employees (total personnel requirements), calculated on the basis of the model function, 2021, 2023, 2026, 2030: — 2021; - - - 2023; - · - · - 2026; · · · 2030. Source: authors' calculations.

FORECAST OF THE NUMBER AND OUTFLOW OF PEOPLE EMPLOYED IN THE ECONOMY

Since a good approximation of the experimental data by the model function of employment levels was achieved in the retrospective period, this approach was extended to the forecast period. It is assumed that the size of the permanent population is determined by natural demographic trends (there is no labor migration), and the growth of the gross regional product is due to a positive change in labor productivity.

Taking into account the dynamics of employment levels for men and women at retirement ages 55+ and 50+, respectively, a "step" appears on the model function of employment levels at older ages, illustrating the change in employment levels with a change in retirement age. The formation of a series of "steps" for men refers to the ages of 55–60 years with an initial employment level of 0.7 at 55 years; for women, to the ages of 50–55 years with an initial employment level of 0.8 at 50 years. Since the retirement age changes every two years, the steps in employment levels also change every two years, meaning they are the same for, for example, 2026 and 2027. Differences in employment levels at retirement age between men and women will subsequently be reflected in the values of the outflow rates. Employment levels at younger ages remain unchanged (Fig. 8).

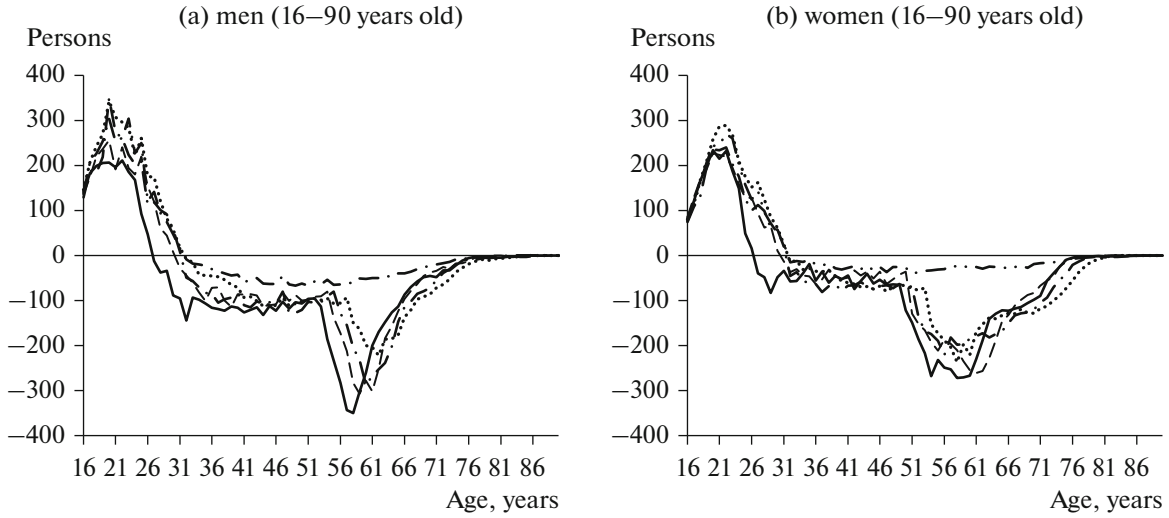

Fig. 10. Annual inflows and outflows in the number of employed people by age in the retrospective and forecast periods, 2020, 2022, 2024, 2027, 2030: — 2020; - - - 2022; - · - · - 2024; - · · - · · - 2027; · · · 2030. Source: authors' calculations.

The value of the number of employed people by annual age categories, taking into account these functions, calculated for 2021–2023, is shown in Fig. 9. The calculation took into account the permanent population size for 2021–2023, respectively, and employment levels were used for 2023 with a limit of one unit of the share of employed people for younger ages.

The integral value of the number of employed (the volume of the total personnel requirement), obtained by summing by age for the periods under review, for men is 125.8 thousand people in 2021, 122.5 thousand in 2023, 117.9 thousand in 2026, and 112.2 thousand in 2030. Similar values for women: 127.6 thousand in 2021, 125.6 thousand in 2023, 124.8 thousand in 2026, and 120.8 thousand in 2030.

The values of the number of employed in the permanent population calculated in this way on the basis of the model function are close to the values shown in Figs. 1 and 6—the difference between the total number of employed in both cases was 1–2%.[12]

Changes in the number of people employed (outflows and inflows), calculated for the current year in relation to the previous one, are shown in Fig. 10.

The shape of the curve and the values of the outflow indicators correspond to the ideas about the dynamics of movement by age of the employed population. The influx of employed people occurs between the ages of 17 and 26 and is associated with the completion of education and the beginning of work.

The main outflows occur at ages above retirement age. Women experience a greater outflow than men at retirement ages. Outflows in the age range from 30 to retirement age are insignificant and are associated with industrial and domestic injuries and changes in residence. For men, the outflows at these ages are greater than for women.

Figure 11 shows a diagram of the increase in the retirement age for the population of the Republic of Karelia. In the framework of this study, given the availability of initial data broken down by one-year age categories with an annual frequency, the retirement age is increased by one year every two years. This approach is consistent with the change in the age limits of working age according to the Rosstat methodology.[13]

Figure 12 shows the dynamics of the natural age-related attrition rates, formed on the basis of the number of outflows for men and women.

The outflow rates alternate at two-year intervals: in odd-numbered years, preretirement workers continue to work, and the outflow decreases. In even years, on the contrary, the outflow increases. Thus, in 2021, the retirement age was raised, the number of employed people increased and, as a result, the outflow decreased and amounted to 2.2% for men and 2.7% for women. After the completion of the pension reform, the outflow rates for men and women reach a steady level and are in the range of 3.7–3.9%.

[12]The median absolute deviation (MAPE), which is a measure of statistical dispersion, for historical indicators is: MARE(2021) = 20.2%; MARE(2023) = 15.6%. The coefficient of determination is R2(2021) = 0.963; R2(2023) = 0.968. The relatively high MAPE value is associated with deviations of model and experimental values in the region of the plateau of the superlognormal distribution (Fig. 7). In the areas of growth and decline of the distribution function, the MAPE value is significantly smaller.

[13]Order of the Federal State Statistics Service of July 17, 2019, No. 409 On Approval of the Methodology for Determining Age Groups of the Population. https://docs.cntd.ru/document/560682671.

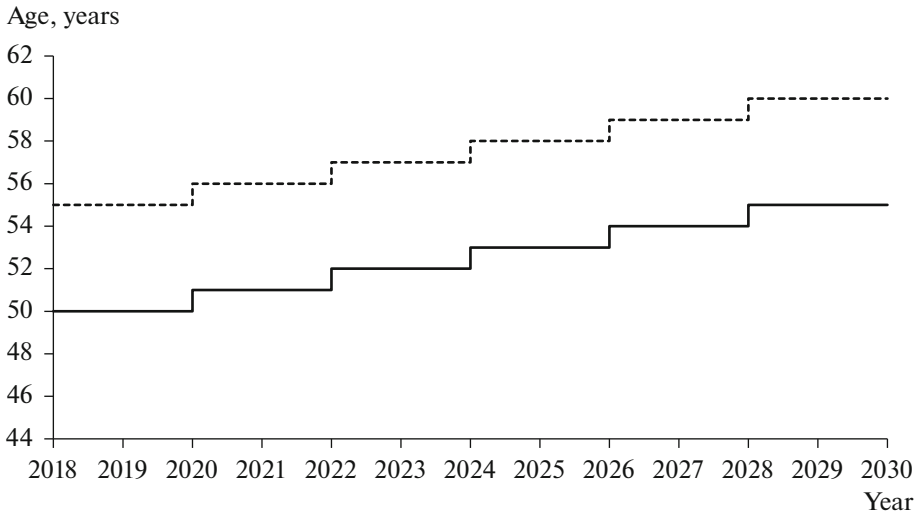

Fig. 11. Retirement age for men (55–60 years) and women (50–55 years), 2018–2030: - - - men; — women. Source: compiled by the authors.

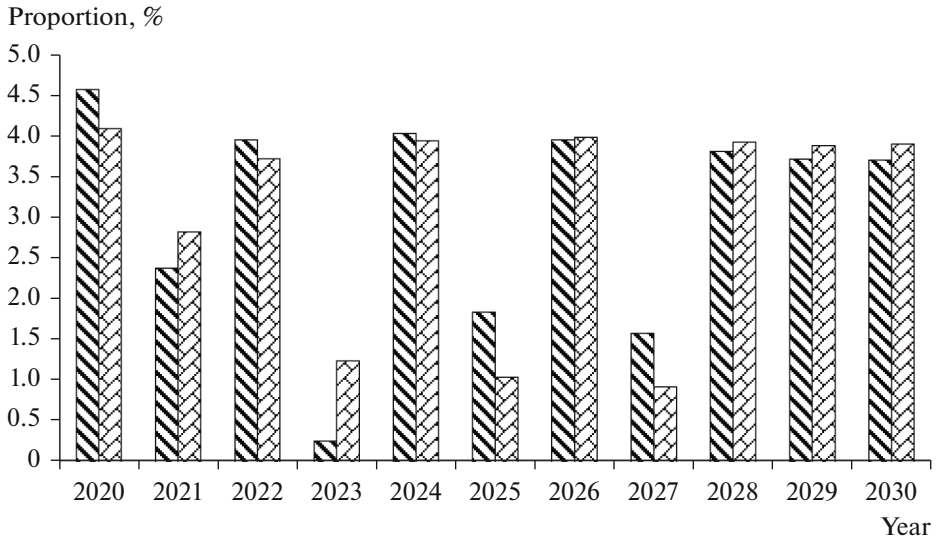

Fig. 12. Natural age-related attrition rates in the employed population among men and women, 2020–2030: men; women. Source: authors' calculations.

CONCLUSIONS

During the study, a new method for calculating forecast indicators of total and replacement personnel needs was developed and tested, based on microdata from sample surveys of the labor force in regions of the Russian Federation. The forecasting method is based on the use of profiles of employment levels by annual age categories when calculating the number of employed people by annual age and gender categories for the actual and forecast periods. The algorithm for implementing the method contains the following steps:

1) Downloading microdata from sample surveys of the labor force by annual age categories, taking into account gender composition.

2) Scaling the results of the sample survey to the entire number of employed people from the permanent population of the region.

3) Carrying out a procedure of double smoothing of scaled data and forming indicators of the number of employed persons by annual age categories.

4) Formation of indicators of the number of permanent population by annual age categories.

5) Calculation of employment levels of the permanent population in the retrospective period.

6) Selection of parameters of the model function in the form of a superlognormal distribution modified by a power factor to approximate retrospective calculated employment levels.

7) Taking into account in the forecast model function of employment levels at older ages "steps" reflecting the change in employment levels with a change in the retirement age.

8) Formation of forecast values of the number of employed people, calculated on the basis of the model function, in the context of one-year age and sex categories. Determining the volume of total personnel requirements by summing up the forecast values of the number of employed by age.

9) Calculation of inflows and outflows in the number of employed men and women by annual ages in the retrospective and forecast periods. Summarizing the outflow of employed people by age to determine the total volume of replacement personnel needs of the economy.

10) Visualization of the natural age-related attrition rate over the time horizon of the implementation of the pension reform.

The practical significance of the study lies in the fact that the developed algorithm for calculating forecast indicators of general and replacement personnel needs can be used by other researchers and employees of executive authorities of the constituent entities of the Russian Federation to substantiate management decisions in the field of labor market regulation. The replacement personnel requirements indicators will serve as the basis for establishing admission targets for educational institutions in the region.

A limitation of the new methodology is the assumption that the dynamics of change in the size of the permanent population and employment levels across age and gender categories will be maintained. The direction of further research is to test the proposed methodology on indicators of other subjects of the Russian Federation.

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CONFLICT OF INTEREST

The authors of this work declare that they have no conflicts of interest.

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