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Modeling the Economy's Need for Professionally Trained Personnel

V. A. Gurtov, E. A. Pitukhin, and L. M. Serova

Abstract—Algorithms and mathematical models that help predict, on the basis of macroeconomic analysis, the needs of regional economies for professionals with higher, secondary, and basic vocational education and form the enrolment plans of educational establishments on the basis of these needs are considered. The model is based on the matrices of profession–qualification matches; it uses job rotation coefficients and average annual employment data by industry and by education level. The methodology of predicting the needs for vocational education graduates is standardized for all the constituent entities of the Russian Federation.

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Education in Russian society is designed to meet personal needs for knowledge, talents, and skills, as well as the economy's market-driven need for qualified personnel. There is high interest in interrelations between the labor market and the market of educational services. The Russian president's message to the Federal Assembly of the Russian Federation [1] notes that "Today, vocational training has no sustainable link with the labor market …. We should ensure that the majority of graduates work in their specialties. We are not speaking, of course, about a return to directive assignment but about predicting the needs of the state for its specialists…."

The targets of coupling vocational education and the labor market, formulated in the Russian president's message, need careful methodological examination [2, 3] to match the number and level of vocational graduates' qualifications with the long-term needs of the labor market.

ALGORITHMS AND MODELS FOR PREDICTING THE ECONOMY'S NEED FOR VOCATIONAL EDUCATION GRADUATES

Principal approach. The system of mathematical models that describe the dynamic interrelations between the economy, labor market, and vocational education served as the basis for solving analytical and prognostic problems of this research [4].

The low level of interregional labor and student migration allows us to consider the federal constituent members as closed systems, make prognostic evaluations at the regional level, and calculate Russia's aggregate need by summing up the needs of the federal constituents.

The diagram of the generalized model of a regional socioeconomic system (Fig. 1) has four fields: the system of general (basic) education, the system of vocational education, the labor market, and the economy.

These fields reflect the temporal stages of the flows under study, the main of which are human (labor) resources. This flow enters the diagram as a birthrate vector; goes through the systems of basic, general, and vocational education; comes to the labor market; and then flows into the economy, creating the gross regional product (GRP) at the "output." The human being in this diagram is a labor resource necessary to produce goods and services.

In addition to the direct problems of analyzing and predicting the development of such a system, it is necessary to consider the inverse problems of optimizing the outputs of educational establishments (EE), controlling the enrolment in EE by necessary specialties. Specialists are needed to implement the adopted GRP growth rates of a region. At the same time, a problem arises of matching the needs of the economy for specialists with the capacity of the educational system to train the required number of skilled specialists for each industry by a certain time.

The most efficient solution to this problem is to identify the number of EE enrollees necessary for the regional economy (marked with a dashed line in Fig. 1) with regard to specialties and education levels. A tool to implement this can be a government order with target enrolment numbers for the establishments of vocational education.

The range of problems related to the prediction of the economy's needs for professionally trained labor has been studied in detail over recent years. Overviews of macroeconomic models are given in the monographs by V.A. Kolemaev [5], E.A. Pitukhin, and V.A. Gurtov [4]. A model that links the number of employees with economic parameters is given in S.V. Dubovskii's paper [6] and is developed in [7]. The prognostic needs of the Russian labor market are analyzed in A.G. Korovkin's monograph [8] and in Gurtov's papers [3, 4]. Prognostic evaluations of educational flows are given in the papers by A.F. Kiselev, A.Ya. Savel'ev,

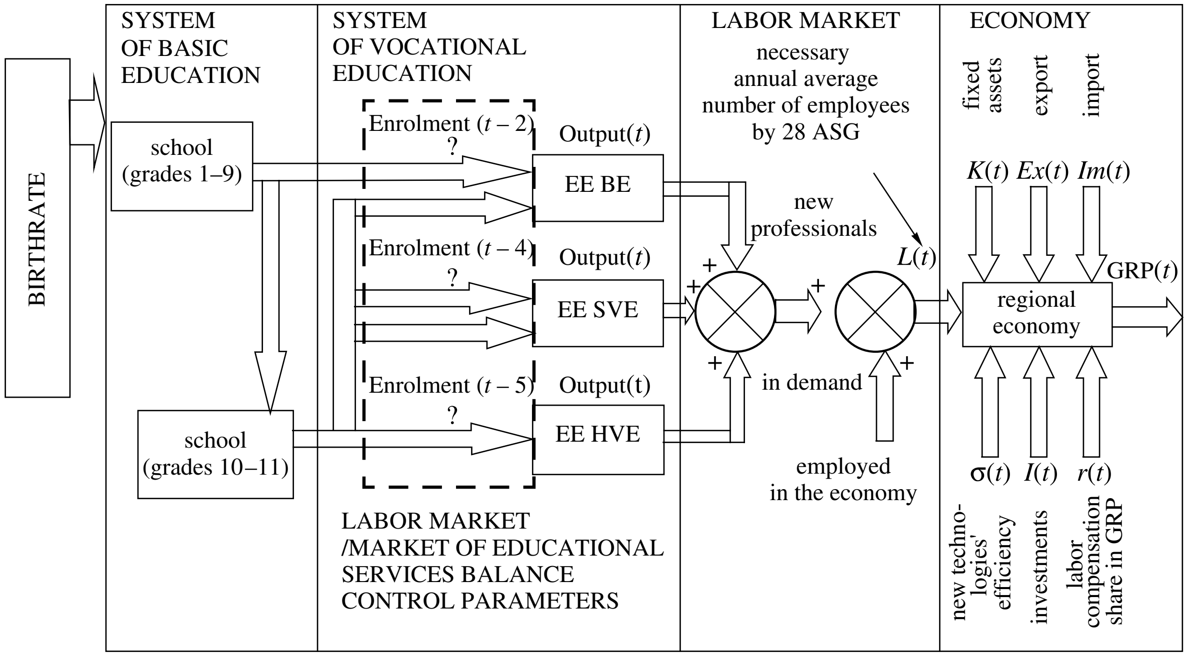

Fig. 1. The structural model of the dynamic system “the economy–the labor market–vocational education.
BVE is basic vocational education,
SVE is secondary vocational education, and
HVE is higher vocational education.

and B.A. Sazanov [9]; A.Yu. Apokin [10]; and the authors of this paper [3, 11].

Nevertheless, these publications do not present models for a complex analysis of supply and demand in the labor market and in the market of educational services and for quantitative assessment of the labor market’s demand for specialists with different levels of vocational education. The structural diagram of the dynamic system “the economy–the labor market–vocational education” (Fig. 1) makes it possible to develop a complex macroeconomic model. Below we review separate blocks of this model in detail.

The economy block (scenarios of economic development and the forecast of the required number of employees). It is fairly difficult to predict how stable the investment inflow would be in each industry and what changes it would produce in the structure of these industries [12]. We suggest building several scenarios of economic development and then predicting personnel needs for each of them [13]. Regional programs of socioeconomic development are developed by the executive bodies of the federal constituents, coordinated with the federal bodies of economic control, and approved by regional legislatures [12].

If the statistical data, presented in the economy block in Fig. 1, are available for a region under study and the relevant economic scenario is chosen, then, in order to model the GRP of an industry with regard to the number of employees, we can use the production function with endogenous scientific and technological progress (after Harrod) from Dubovskii’s nonstationary model of the Russian economy [6] with discrete time:

$$(X(i+1)-X(i))/X(i) = \alpha(K(i+1) - K(i))/K(i) + (1-\alpha)((L(i+1) - L(i))/L(i)) + \sigma I(i)/K(i), \quad (1)$$

where $X(i)$ is the gross regional product (GRP); $L(i)$ is the number of the employed or employees; $K(i)$ is the fixed assets; $I(i)$ is investments; [alpha] is GRP elasticity to assets; [sigma] is the efficiency of new technologies in labor productivity; and i is a year.

Here, the summand $\sigma I(i)/K(i)$, the growth rate of the economy’s technological level, reflects increasing labor productivity owing to the emergence of “pseudoemployees.” Together with the growth rate of employment $(L(i+1) - L(i))/L(i)$, they comprise the rate of economic growth [6]. The impact of scientific and technological progress (STP) here is working from within, endogenously. If significant regressive evaluations of parameters [alpha] and [sigma] are derived, the production function model (1) will be more adequate to reality than when STP is set exogenously, which is also proved by a similar ratio derived from the mathematical models in [14].

Calculation practice shows that it is difficult to obtain all necessary statistical information on the current and planned investments, fixed assets, and the number of employees by industry in a federal constituent.

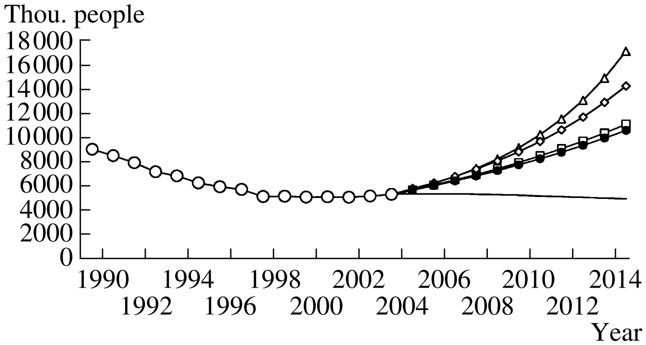

Fig. 2. Different options of change in the number of employees in the construction industry:
(—) noninterference scenario, (–◇–) linear growth of labor productivity, (–□–) geometrical growth of labor productivity, (–●–) exponential growth of labor productivity, (–△–) decelerating growth of labor productivity, and (–○–) retrospect.

When neither data nor forecasts on the fixed assets and investments over a retrospective period are available, then, in order to evaluate the number of employees, trends in changing labor productivity are extrapolated on the forecast period. In such cases, the derived number of employees $L(i)$ is viewed as a regional need for labor by industry. Such evaluations correspond to “control scenarios,” since the number of employees in an industry depends on planned changes in the GRP.

We also consider an “intervention scenario,” in which the changing number of employees in an industry does not depend on the expected GRP change, and it is calculated on the basis of the extrapolative evaluation of changes in regional labor resources. The calculation of the number of specialists that can be obtained from regional labor resources is reduced to finding a regression between the forecast number of regional population at the working age $Lab(i)$ and the number of employees in the economy $L(i)$.

The choice of the most probable scenario for forecasting the total number of employees is made expertly according to research goals.

We considered as examples the basic scenarios of Russia’s economic development with GDP growth up to 75% by 2015 compared to 2005 and investment-backed scenarios with GDP growth up to 100%. Any of these scenarios implies a certain percentage of growth in the need for skilled labor, assuming that labor productivity is constant. On the basis of the previous demographically justified forecast of an average two-time decrease in the number of graduates from all establishments of vocational education by 2015, we can make a raw estimate: labor productivity in nonextracting industries must improve up to four times. Korovkin, I.N. Dolgova, and Koroleva [15] give a macroeconomic evaluation of the demographic impact on the economy, which creates labor deficit.

Figure 2 shows general labor dynamics typical of the construction sector in Russia.

The four top curves show the need for skilled labor under the different growth rates of labor productivity in a given industry owing to the implementation of a national housing project. In addition, it is assumed that the normative plan of doubling the gross product of the construction industry by 2010 compared to 2004 will be implemented if the GDP growth rate in the industry remains constant at about 15% a year. The bottom curve reflects the noninterference scenario and extrapolates the trend of annual reduction in the number of employees in the construction industry within the general limitation on Russia’s working population.

The dynamics of change in the number of employees was calculated under different evaluations of changing labor productivity. Under the linear growth of labor productivity, a regression equation was built for labor productivity starting with 1998; under decelerating growth, the growth rate of labor productivity was reduced to one by 2015; under the geometrical growth, the geometric mean of the growth rate was calculated from 1998 through 2004; and under exponential growth (social mobilization), an autoregression equation was built.

On the basis of the obtained evaluations (see Fig. 2), we can judge about the degree of interference in the training of skilled labor necessary for the implementation of the national housing project in the construction industry. We can see that to double the GDP, it is necessary to either double the number of employees or improve significantly labor productivity in the industry. At the same time, under any forecast option of labor productivity growth, we see an additional need for skilled labor in the industry, compared to the noninterference scenario and the retention of the existing trends.

A labor productivity improvement is possible under a serious increase in investments into the science-and-technology component of economic growth. Inability to improve labor productivity in all industries and industrial sectors necessitates the prioritization of industries for skilled labor supply. It is obvious that only “selected” industries can meet 100% the need for skilled labor in order to reach the planned economic growth rates under a slight improvement in labor productivity, and these industries will fight for this labor resource by financing training and providing their employees with better socioeconomic conditions.

The economic system’s parameters calculated in [6] show a low share of labor compensation in regional GRPs, as compared to similar indicators in developed market economies. This is probably the cause of the low attractiveness and prestige of professions provided by basic and secondary vocational training, since the share of employees with basic and secondary vocational education in the employment structure is much lower than the optimal proportion. This situation may be resolved by gradually restoring the balance between the labor market needs and the capacities of the market of educational services.

The labor market block (the industries' annual need for skilled labor). Note that different needs make up the need for skilled labor: (1) the replacement of naturally retired employees, including age qualifications; (2) the replacement of personnel deficit owing to unsatisfactory working conditions (low salaries and wages, the absence of social packages, a low social status, a tight labor schedule, etc.); and (3) providing personnel for new competitive producers of goods and services. When determining the demand for personnel in this paper, we used need (1) for the noninterference scenario and needs (1) and (3) for the control scenario. Need (2) is hard to formalize; therefore, it is currently not used in models.

The calculation of the need of the industries of a regional economy for graduates from the system of vocational education includes the following stages [16, 17, 18]:

• the determination of the total number of employees in the economy $L(i)$ was previously carried out in the economy block.

• the forecast of distribution of employees by industry in the economy and the social sphere. This problem is resolved similarly to the case with the total employment $L(i)$. As a result, we have multiple forecasts $L_l(i)$, where l is one of 13 industries.

• The forecast of distribution of employees by education level and by industry. The obtained forecast of the number of employees by industry should be divided into educational levels. The share of employees with the assigned educational level in an industry is extrapolated by retrospective data to the future. As a result, we have $L_l(i)$ distributions by educational levels $L_{l_V}(i)$, $L_{l_C}(i)$, and $L_{l_N}(i)$—a forecast of the need of industries in employees with higher (V), secondary (C), and basic (N) education.

• The calculation of the coefficient of annual renewal (a reciprocal value of the job rotation coefficient) of the employed population by industry. This coefficient depends on the educational level and is determined empirically. For instance, for higher education, it is about 4%, and the corresponding job rotation coefficient is $R_V = 1/0.04 = 25$. For secondary education, this rotation coefficient is also high, $R_C \in [20\ldots25]$, and for basic education, it is low enough, which is due to a high job rotation among BE specialists, $R_N \in [15\ldots20]$. The job rotation coefficient serves as the basis for calculating the share of the annual renewal (demand for specialists) with the relevant educational level for each industry; for example, for higher education, it will be $L_{l_V}(i)/R_V$.

• The construction of a normative matrix of the weighing coefficients of the profession–qualification distribution of graduated specialists for 28 aggregate specialty groups (ASGs) in 13 industries and 14 industrial sectors. The lines of this matrix correspond to 13 industries (the l index of industries), and columns, to 28 aggregate specialty groups (the k index of aggregate specialty groups). This matrix is normative and unique for each educational level O, $O \in \{V, C, N\}$: its element $a_{O_{l,k}}$ corresponds to the percentage of specialists with the educational level O with the k[th] aggregate specialty group, who are traditionally recruited to the industry l. This matrix allows us to recalculate the annual need for the specialists $Pt_{O_k}(i)$ with the educational level O from the l profile of industries to the k profile of the aggregate specialty groups:

$$Pt_{O_k}(i) = \left[\sum_{l=1}^{13} a_{O_{l,k}} L_{l_O}(i)/R_O\right]. \qquad (2)$$

When going from the All-Union Classifier of the National Economy's Industries (OKONKh) to the All-Russian Classifier of the Types Economic Activities (OKVED), we retain the normative matrix approach and take into account changes in the lines of the matrix of profession–qualification correspondence from the national economy's industries to the types of economic activities.

This matrix approach to forecasting the needs of the Russian labor market for professions and qualifications was proposed in [3, 16]. It has turned out that a similar approach is actively used by the US Bureau of Labor Statistics [3].

The vocational education block (an opportunity for training skilled personnel). Here are several basic assumptions:

(1) Graduates from grades 9 and 11 of secondary schools and citizens with general secondary education have only three options to receive vocational education:

—EE of basic vocational education (BVE) with a two-year term of study,

—EE of secondary vocational education (SVE) with a four-year term of study, and

—EE of higher vocational education (HVE) with a five-year term of study.

(2) Those willing to study are not allowed to enter simultaneously two or more educational establishments.

(3) Processes (events) that are not related to entering an EE (service in the army, unskilled work without vocational education) are considered in these models.

According to the accepted methodology [11], model parameters are determined as follows:

• flow distribution parameters are the weighing coefficients of distribution of students by establishment of vocational education.

• parameters of external control inputs are vectors $U_9(i)$ and $U_{11}(i)$ of 9- and 11-grade graduates of a federal constituent.

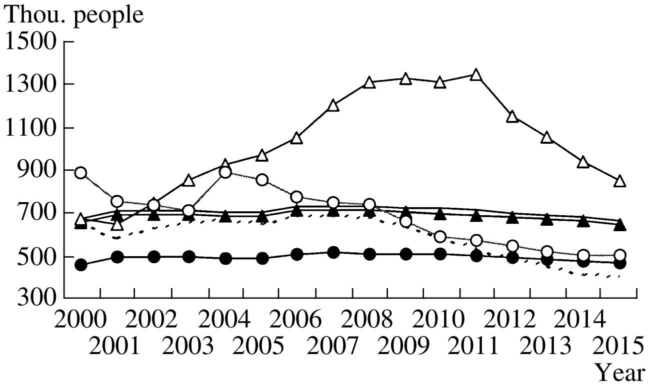

Fig. 3. The Dynamics of the annual need for the Russian economy's employees by vocational education level according to the noninterference scenario and the dynamics of specialist output from the Russian system of vocational education:

(–▲–) The annual need for employees with HVE, (—) the annual need for employees with SVE, (–●–) the annual need for employees with BVE, (–△–) SEE HVE output, (----) SEE SVE output, and (–○–) SEE BVE output.

• As controlled variables, we have EE entrance flows, which are formed according to a certain program or plan.

The ratios of EE output (graduate) flows to input (entrance) flows are expressed through transfer functions. In the simplest case, they are constants, then:

$$V_V(i) = K_V P_V(i-5), \quad V_C(i) = K_C P_C(i-4), \quad V_N(i) = K_N P_N(i-2), \tag{3}$$

where K_N, K_C, and K_V are transfer function coefficients (attrition coefficients) for the three levels of education; $P_O(i)$ is entrance to EE of level O; $V_O(i)$ is EE graduates of level O.

To determine EE transfer function coefficients for each region, we used the methods of linear regression, autoregression, and time-trend averaging.

The mathematical model of graduate flow distributions, which is universal for all the federal constituents, is formalized as a system of three finite-difference equations:

$$\begin{aligned} P_N(i) &= U_9(i-1)(K_{r9r}^N + K_{9r}^N) + U_{11}(i-1)K_{11r}^N \\ &\quad + U_9(i)(K_9^N + K_{r9}^N) + U_{11}(i)K_{11}^N; \\ P_V(i) &= P_N(i-2)K_N K_N^V + P_C(i-4)K_C K_C^V \\ &\quad + P_N(i-3)K_N K_{Nr}^V + P_C(i-5)K_C K_{Cr}^V \\ &\quad + U_{11}(i)K_{11}^V + U_{11}(i-1)K_{11r}^V; \\ P_C(i) &= U_9(i)K_9^C + U_{11}(i)K_{11}^C + U_9(i-1)K_{9r}^C \\ &\quad + U_{11}(i-1)K_{11r}^C + P_N(i-2)K_N K_N^C + P_N(i-3) \\ &\quad \times K_N K_{Nr}^C + P_C(i-5)K_C K_{VCr}^C + P_V(i-6)K_V K_{VCr}^C. \end{aligned} \tag{4}$$

In equation system (4), coefficient K_X^Y with superscripts and subscripts stands for transfer functions that designate a share of flow X directed into flow Y. For instance, K_{11}^V is a share of 11-grade graduates of this year who entered EE HVE in the current year. Index r designates the previous year; for example, K_{Cr}^V is the share of EE SVE graduates from last year who entered EE HVE this year.

Model (4) describes inputs and outputs without breaking them into specialties. This is not enough to solve the balance problem, since it is necessary to observe the identity of dimensions. To eliminate this discrepancy, model (4) is written k times separately for each of the 28 ASGs and is united into an integral network model that accounts for the horizontal migration of students as they enter large educational centers. The total number of zero parameters in the new integral system, taking into account all the 86 federal constituents, will be more than 150 000, and the number of levels, more than 7000.

The block of the labor market/market of educational services balance. This block deals with balance building: the comparison of the forecast needs of industries and industrial sectors for the graduates of the vocational education system by model (2) and the forecast capacities of the vocational education system to meet the needs of the 28 ASGs by model (4).

Figure 3 shows the resultant curves of the forecast need for employees of different levels of vocational education in the Russian economy from 2006 through 2015 (solid line) and the forecast output from the state establishments of vocational education (SEE) (dashed line) provided the existing trend continue.

The above graphs reflect the situation in Russia, which is similar to the situation in many Russian federal constituents. Figure 3 shows that the EE HVE output exceeds substantially the economy's need for specialists with higher education. At the same time, the Russian economy needs skilled labor with secondary vocational education, but the imbalance at this level is only increasing with time. The total number of EE BVE graduates will lag behind the need for them starting with 2007. Bearing in mind that only 50% of EE BVE graduates find jobs, the imbalance between the need and the output of specialists with BVE will increase; i.e., the share of specialists will decrease by working profession.

The software implementation of algorithms and models allows us to make prognostic calculations of the economy's needs for specialists in the regional and industrial aspects and the outputs of EE of different levels.

Figure 3 shows integral characteristics but does not reflect the situation in terms of specialties. Figure 4 details the need and outputs for the Republic of Karelia's EE HVE for 2010 in terms of ASGs.

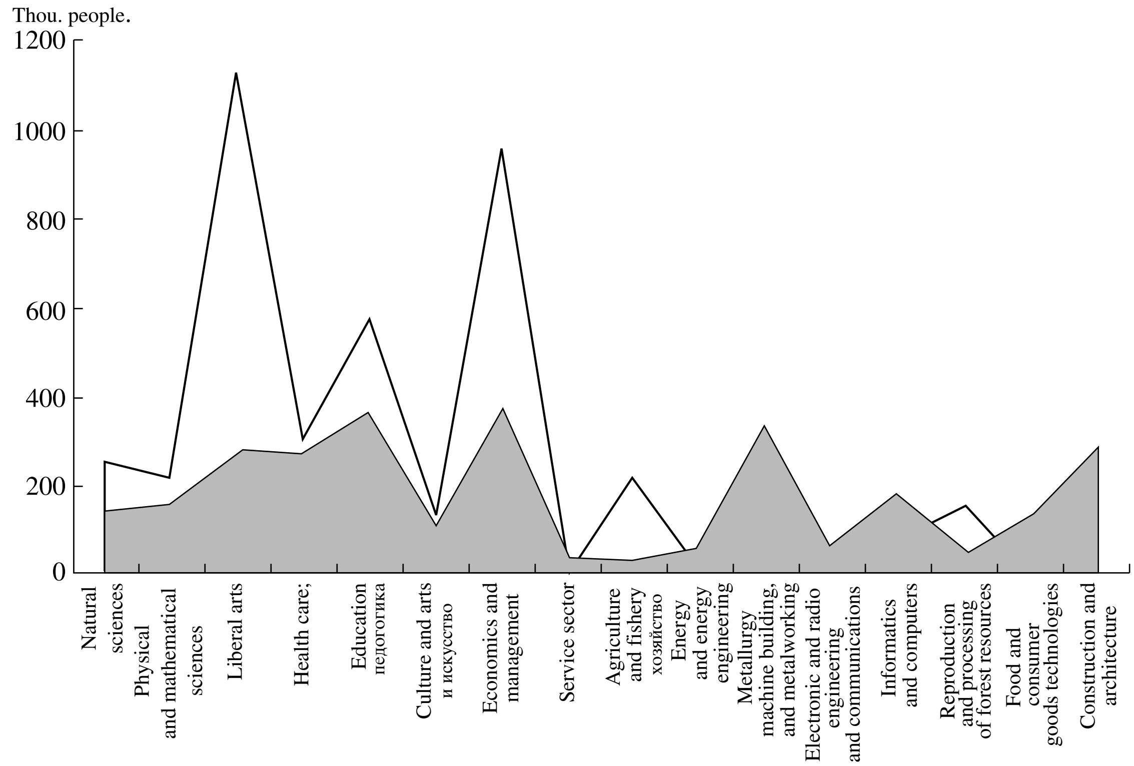

Fig. 4. The forecast need of the Republic of Karelia's economy for EE HVE graduates (□) and the forecast output from full-time EE HVE by ASG (▩) for 2010.

Figure 4 shows imbalance in training specialists within the HVE level. The main excess of supply over demand falls on the ASGs Humanities (+326%), Economics and Management (+144%), and Education (+53%). On the contrary, deficit is expected in the following most demanded ASGs: Metallurgy, Machine Building, and Metalworking (–65%), Informatics and Computers (–57%), and Construction and Architecture (–47%).

Such a situation is characteristic of many Russian federal constituents (Table 1).

Table 1 shows a positive balance at the HVE level for the regions under study and Russia as a whole (a surplus of specialist training) for the ASGs Humanities and Economics and Management in 2005, which will continue until 2015 (the respective averages for Russia are +7 and +15%). The ASG Metallurgy, Machine Building, and Metalworking will, on the contrary, experience an increasing labor deficit, which will reach –10% for Russia by 2015, compared to the current –6%. A similar picture is observable in the levels of secondary and basic vocational education.

Owing to a demographic slump, the output from the establishments of vocational education will drop significantly and affect the balance ratio by 2015. The integral indicators of personnel training show that, from the four regions represented in Table 1, only Tomsk oblast will have a slight surplus of EE HVE and BVE graduates over the need for them by 2015 [19]. This is predetermined by the fact that Tomsk oblast is a federal educational megalopolis where people come to receive higher education from other Russian regions: Kemerovo oblast, Krasnoyarsk krai, Tyumen oblast, the Republic of Khakassia, Altai krai, etc.

A more detailed analysis of prognostic evaluations of the needs of Russian industries in specialists with vocational education (HVE, SVE, and BVE) for the period until 2015 shows that, by 2010 on average in Russia, the industry Industry will need 766000 specialists and the education system will provide only half of them for it (390000). At the same time, the industry Wholesale and Retail Trade will be oversupplied with specialists more than two-times: 195000 graduates against the need for 82 000. The industry Management will need 38 000 specialists and will receive 76000 graduates; the industry Agriculture and Forestry will have to meet its need for 47000 employees from 124000 graduated specialists.

The conducted analysis shows a significant imbalance in the system of Russian education regarding the quantity–qualification ratio of graduated specialists to the economy's needs.

In order to find the optimal number of graduates that would match the outputs of the institutions of vocational education with the needs of the industries of

Table 1. The balance of specialist output and the need for them by ASG for different levels of vocational education for Tomsk oblast, the Republic of Sakha (Yakutia), the Republic of Karelia, and Russia as a whole

Education level	Federal constituents	Humanities						Economics and management					
		2005		2010		2015		2005		2010		2015	
		people	%	people	%	people	%	people	%	people	%	people	%
HVE	Tomsk oblast	2106	14.1	1680	13.9	1084	13.4	3340	22.4	2599	21.5	1601	19.8
	Republic of Sakha	964	15.8	1046	15.6	780	15.2	1160	19.0	1243	18.6	880	17.1
	Republic of Karelia	880	20.3	705	19.4	401	17.0	785	18.1	584	16.1	294	12.5
	Russian Federation	97806	9.8	82421	9.2	42842	6.9	199707	20.1	170647	19.1	95262	15.4
SVE	Tomsk oblast	394	7.3	214	5.7	113	4.0	840	15.6	381	10.2	120	4.3
	Republic of Sakha	313	6.8	296	6.7	185	5.5	347	7.5	311	7.0	81	2.4
	Republic of Karelia	10	0.3	–24	–0.9	–48	–2.7	599	16.2	310	11.7	96	5.3
	Russian Federation	41581	6.0	26067	5.0	15430	4.0	118714	17.2	69721	13.5	36983	9.7
BVE	Tomsk oblast	27	0.4	13	0.4	14	0.4	683	10.9	246	7.2	274	7.7
	Republic of Sakha	–10	–0.3	–10	–0.3	–9	–0.4	–69	–1.9	–125	–4.2	–160	–6.7
	Republic of Karelia	42	1.0	21	0.8	17	0.8	377	9.0	144	5.6	101	4.7
	Russian Federation	–596	–0.1	–1043	–0.2	–1020	–0.3	27644	4.1	–1047	–0.2	–4428	–1.2

Education level	Federal constituents	Metallurgy, machine building, and metalworking						By all specialty groups					
		2005		2010		2015		2005		2010		2015	
		people	%	people	%	people	%	people	%	people	%	people	%
HVE	Tomsk oblast	–908	–6.1	–1083	–8.9	–1132	–14.0	9490	63.7	6126	50.6	2146	26.7
	Republic of Sakha	–847	–13.9	–974	–14.6	–942	–18.4	1532	25.1	1280	19.1	–60	–1.2
	Republic of Karelia	43	1.0	–105	–2.9	–140	–5.9	2255	52.1	1071	29.5	–10	–0.4
	Russian Federation	–56896	–5.7	–59408	–6.7	–62606	–10.1	195874	19.7	102725	11.5	–119595	–19.3
SVE	Tomsk oblast	–773	–14.4	–785	–20.9	–783	–27.7	–402	–7.5	–1984	–52.9	–2866	–101.6
	Republic of Sakha	–642	–13.9	–638	–14.4	–622	–18.6	–2410	52.1	–2538	–57.2	–3349	–100.0
	Republic of Karelia	–242	–6.5	–253	–9.5	–246	–13.7	–581	–15.7	–1455	–54.9	–1964	–109.3
	Russian Federation	–77847	–11.3	–84151	–16.3	–82066	–21.5	–84058	–12.2	–246324	–47.7	–322470	–84.3
BVE	Tomsk oblast	–215	–3.4	–473	–13.9	–453	–12.7	3386	54.0	537	15.8	721	20.2
	Republic of Sakha	–612	–16.9	–668	–22.5	–687	–28.8	–324	–8.9	–959	–32.4	–1380	–57.8
	Republic of Karelia	–49	–1.2	–200	–7.8	–205	–9.6	1566	37.4	38	1.5	–175	–8.2
	Russian Federation	–47809	–7.0	–75890	–17.9	–73645	–20.4	129119	19.0	–119027	–28.1	–140092	–38.8

Note: The balance is seen as the difference between the output of students from state and private EE by all modes (full-time, part-time, extramural, and external) and types (federal budgetary and full cost-recovery) of education and the economy's need for graduates.

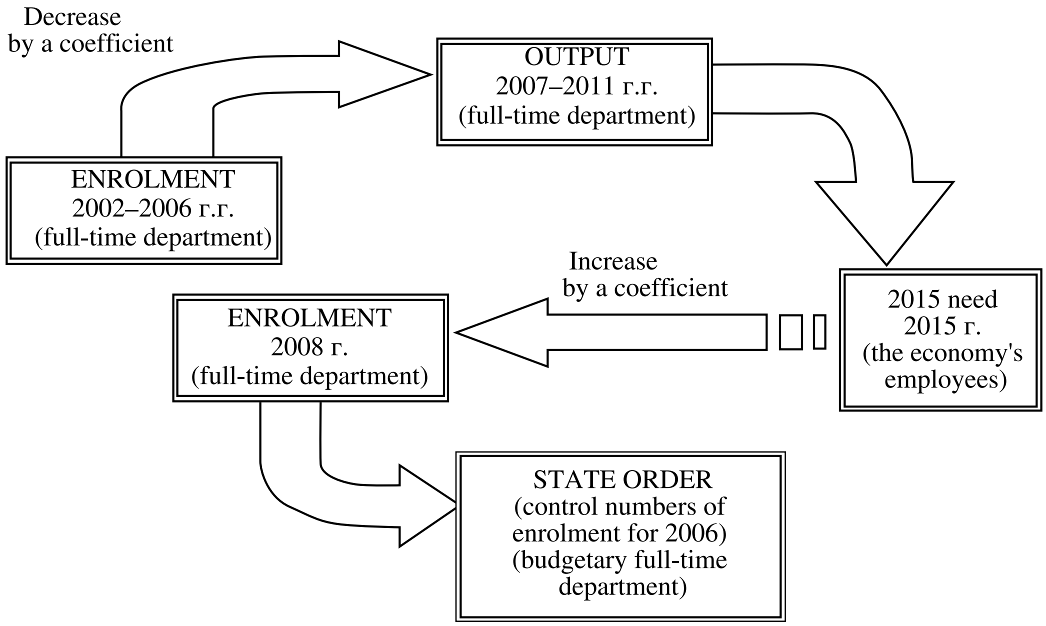

Fig. 5. The diagram of the methodology of forming a state order (control numbers of enrolment) according to the economy's need.

regional economies, it is necessary to solve a reciprocal balance problem.

$$V_{O_k}(i) = Pt_{O_k}(i), \quad \forall O \in \{V, C, N\}. \qquad (5)$$

In problem (5), the setting (expected) impact is the right part of the equality, i.e., the needs of industries $Pt_{O_k}(i)$ by specialty and educational level, and the left part of the equality—EE outputs $V_{O_k}(i)$ are project, optimized, parameters, whose values are adjusted to the corresponding needs during the optimization process.

Let us consider a "soft" option of solving problem (5).

The block of forming a state order for training specialists whom the economy needs. The above supply and demand balance tables are the basis for forming the control numbers of enrolment.

We suggest a method that is different from the general problem statement and that is based on the concept of "sparing control." When forming the control numbers of enrolment for the 28 ASGs, this concept uses three basic assumptions [20]:

• orientation toward a regional economy's need for specialists with vocational education;

• primary supply of graduates from the system of vocational education to the economy's priority industries; and

• a gradual transition from the existing enrolments to the formation of the expected control numbers in four or five years.

The diagram in Fig. 5 shows the methodology of forming a state order.

Let us assume that we know the need for specialists at the end of the anticipation period $Pt_{V_k}(i_f)$ to which we should match EE HVE outputs, and we also know the output of this year $V_{V_k}(i_s)$.

Then, the mathematical model of optimal expected outputs $V^*_{V_k},(i_s)$ by the suggested methodology, is built for HVE as a linear interpolation between points i_s and i_f:

$$V^*_{V_k}(i) = V_{V_k}(i_s) + (i - i_s)(Pt_{V_k}(i_f) - V_{V_k}(i_s))/(i_f - i_s). \qquad (6)$$

Therefore, the optimal enrolment in the year $i \in \lfloor i_s, i_f \rfloor$ may be reciprocally evaluated from formula (3) as

$$P^*_{V_k}(i) = V^*_{V_k}(i_s + 5)/K_{V_k}. \qquad (7)$$

On the basis of the described algorithm, we calculated the optimal control numbers of enrolment for the 28 ASGs until 2015 for pilot regions (the republic of Karelia, Tomsk oblast, Perm oblast, and the Republic of Sakha (Yakutia)). It was recommended to decrease enrolment in the groups of humanitarian and economic–managerial specialties and to increase enrolment in the groups of machine-building, information–technical, and construction specialties.

Verifying prognostic outputs from the system of vocational education and the prognostic need of the economy for personnel with vocational education of different levels. Let us quote the postforecast of the 2003 outputs from the system of vocational education, which was derived by the 2003 program version, which

Table 2. The forecast of student enrolments and outputs at the SEE HVE, SVE, and BVE in Perm oblast*

Year	HVE		SVE		BVE	
	Enrol-ment	Output	Enrol-ment	Output	Enrol-ment	Output
2000	18658	8223	20509	11951	25578	25340
2001	19267	8736	21174	12360	26516	24890
2002	18768	9620	20447	13037	26011	22984
2003	19265	10399	20106	15231	25020	23826
2004	20243	13826	19914	16766	23830	23372
2005	20013	16341	18915	17310	21980	22482
2006	18889	16874	17388	16716	19717	21413
2007	17470	16437	15846	16437	17737	19751
2008	16113	16873	14170	16280	15708	17717
2009	14876	17729	13077	15464	14640	15938
2010	13522	17528	11941	14215	13622	14115
2011	12531	16543	11350	12954	13141	13155
2012	11810	15301	10960	11534	12975	12111

Note: * 2000–2001 are actual data; 2002–2012 are forecasts.

Table 3. Initial statistical data on enrolments and outputs at SEE HVE, SVE, and BVE in Perm oblast

Year	HVE		SVE		BVE	
	Enrol-ment	Output	Enrol-ment	Output	Enrol-ment	Output
2000	18958	8841	20759	11936	27300	25000
2001	19166	10225	20984	13200	27200	25200
2002	20656	12394	21100	14749	27200	24706
2003	19900	13523	20800	14668	27200	23300
2004	20185	14888	20722	16241	25676	32947
2005	20969	15389	20109	15675	20592	24470

Table 4. Forecast accuracy evaluations for the period from 2002 through 2005

MREP	4.29	14.70	4.07	7.28	6.58	11.60
MAD	884	1978	837	1109	1651	3453
O	0.946	0.832	0.958	0.918	0.933	0.845

contained data only for 2000 and 2001. This excludes the temptation to "adjust the forecast" in the 2006 version of the program that contained data until 2006 inclusively.

Let us consider the forecast for Perm oblast as an example (Table 2).

In 2003, the 2003 version of the program had only data from the *Russian Regions 2002* reference book, published by the Federal Statistics Service (Rosstat) [21], and the program was fine-tuned by the 2000 and 2001 data.

The actual enrolment and output data from 2002 through 2006 to be later compared with the forecast are given in Table 3 [22].

Table 4 gives three types of forecast accuracy evaluation, calculated for the control sample from 2002 through 2005:

(1) *O* is a forecast evaluation that allows us to evaluate the accuracy of the forecast when we have data on the forecast implementation. The following recommendations to use the evaluation are given in [23]:

- $O > 0.9$, a good forecast;
- $0.8 \le O \le 0.9$, a satisfactory forecast; and
- $O < 0.8$, an unsatisfactory forecast.

It is evident from Table 4 that the evaluation of the *O* forecast is higher than 0.8 and higher than 0.9 in the majority of cases. This is rather a good than a satisfactory accuracy of the forecast.

(2) MREP is the mean relative errors in percent.

(3) MAD is the mean absolute deviations of the forecast value from the actual.

It is clear from Table 4 that all MREP evaluations do not exceed 15% despite a sharp "surge" in the 2004 EE BVE output in the initial data (see table 3). The given evaluations indicate a good forecasting accuracy when compared with the implementation.

To verify the forecast need of the economy for personnel with vocational education is rather difficult, because there are no generally recognized criteria and indices for these characteristics. The recruitment of graduates according to their received specialty and data on vacancies at labor and employment services may serve as guidelines to the economy's needs for personnel. It is also possible to compare calculated forecast needs with alternative forecast evaluations obtained from other models or by the sample polling of employers.

In order to determine the forecast need of organizations that are subordinated to the executive bodies of the federal constituents for specialists with HVE by the full-time mode of study by the 28 ASGs, in 2002, the Russian Ministry of Education developed and sent to the federal constituents fill-in forms No. 1-SF and No. 2-SF (the forecast need for specialists with higher vocational education by the full-time mode of study for the period from 2003 through 2010 by 28 aggregate specialty groups). However, the absence of a single need-forecasting methodology for forms No. 1, 2-SF in the regions resulted in different approaches to the formation of this need, which were often directed at the existing situation in the educational system. In general, the comparison of the calculated needs for specialists with HVE by forms No. 1, 2-SF and the authors' methodology identified a correlation of forecasts by the total need, as well as by the 28 ASGs.

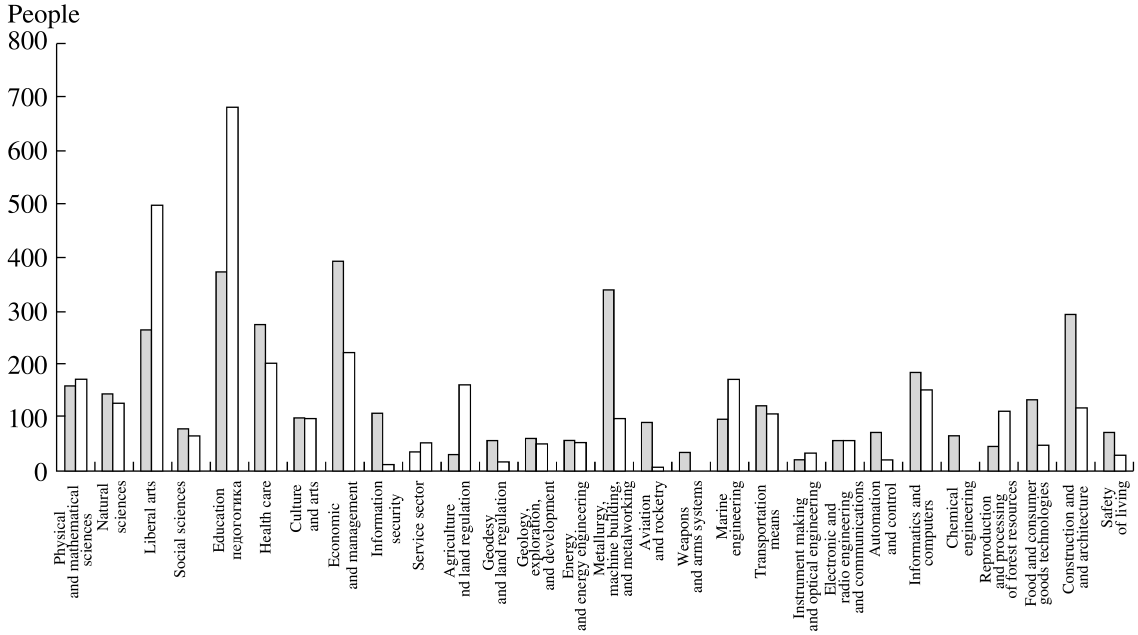

Fig. 6. The comparison of the Karelian economy's need for HVE graduates by form No. 2-SF for 2010, requested by the Karelian executive authorities in 2002 (□), with the results of the calculations by the authors' methodology (▤) (2005).

Figure 6 shows the comparison of the results of the forecast need of the Republic of Karelia's economy for specialists by the authors' methodology and by the turnout of forms No. 2-SF.

To verify the forecast needs for professionals is possible with data on vacancies at the Federal Labor and Employment service, as well as with data on the actual recruitment of graduates. The conducted research has shown that information on vacancies available at local labor and employment services is incomplete, because not all employers apply to the employment services for recruitment. The survey of the recruitment of graduates covers all educational establishments of all levels of education as annual statistical reporting and gives more objective criteria to evaluate the current need of the economy for skilled labor.

In 2005, under the order of the Department of Social
1 and Labor Relations of the Tomsk oblast's administration, the Center of Budget Monitoring of Petrozavodsk State University (CBM PetrSU) generated the forecast need of the economy for qualified labor for Tomsk oblast for 2006. The calculation was based on macroeconomic indices for the period from 1995 through 2004 according to the noninterference scenario. In 2007, a survey was conducted in Tomsk on the employment of the 2006 EE BVE graduates [24]. The comparison of the results of this survey and the calculated need for BVE graduates by the demanded aggregate specialty groups is given in Table 5.

Table 5 shows that data on BVE graduate recruit-
1 ment and the calculated need of the Tomsk oblast's economy for BVE graduates for 2006 have a very high correlation. MREP for different ASGs does not exceed 15%; it is 30–35% only for the ASGs Food and Consumer Goods Technologies and Construction and Architecture. This is due to the priority development of the construction, light, and food industries in 2006. The calculation by the active scenario with account for the prioritized development of industries yields a more accurate forecast.

* * *

Described mathematical models (1–4) represent a generalized model of the system the economy–the labor market–vocational education. They serve as the basis for solving the direct problem of analyzing the dynamics of this system and for calculating different ways of its development. Models (5–7) serve to solve the reciprocal problem of reducing the imbalance between the economy's need and the educational system's output. On their basis, we can calculate the control numbers of enrolment (the state order), which would help reduce significantly this imbalance.

The main advantage of the developed models is in their unification in relation to different regions; these models are identifiable for each out of the 86 constituent members of the Russian Federation; and they help build regional scientifically justified forecasts of the needs of industries for qualified labor and the capacities of the system of vocational education to meet these needs.

The above models comprise the core of a software product, developed as a modeling information–analytical system applicable to justify and make managerial decisions. Such decisions may be directed to improve the efficiency of budgetary spending on education.

Table 5. The comparison of data on the recruitment of EE BVE graduates and the forecast need of the Tomsk oblast's economy for EE BVE graduates in 2006 1

Name of aggregate specialty groups in the BVE system	EE BVE output in 2006 (full-time mode of study)	BVE graduate recruitment	Forecast need for BVE graduates by the CBM PetrSU method, 2006	Forecast need's MREP of graduate recruitment, %
100000 Service sector	770	408	414	–1.47
110000 Agriculture and fishery	663	323	277	14.24
130000 Geology, exploration, and development of mineral resources	120	67	58	13.43
210000 Electronic and radio engineering and communications	94	41	44	–7.32
250000 Reproduction and processing of forest resources	129	78	90	–15.38
260000 Food and consumer goods technologies	663	356	249	30.06
270000 Construction and architecture	348	236	319	–35.17

Russia's budgetary expenditures in 2005 on training 3 million budgeted students in the HVE system were 125.9 billion rubles. According to the indicators of the Federal Education Development Program, in 2005, 30% of EE graduates found jobs related to their specialties within one year, and 70% worked by their specialties. If the number of graduates who work by their specialties increased 1%, the efficiency of budgetary spending would increase more than 1 billion rubles, compared to the initial number of graduates.

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