Model of state and moving of workforce in the region

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Abstract: It is known that education of optimal number of workers with certain speciality is a relevant object for many counties. Economic of the country or some region can not effectively develop without appropriate workforce supply, which generally formed by graduates from educational institutions of professional education. The model of state and moving of workforce in the region aimed at forecasting the condition of labor market in alignment with system of education, which can provide sensible information to governments concerning the current situation in system of education and labor market and to what it leads to. Moreover, model provides the scenario analysis with possibility to regulate admission quotas and collate the optimal number of students with certain speciality.

Key–Words: workforce, forecasting, workforce deficit, system dynamics, AnyLogic, solutions to decrease the workforce deficit

1 Introduction

Federal agencies of many countries, including Russian Federation, responsible for controlling labor market, have pursued high amount of researches aimed at forecasting main values of labor market condition and decreasing the deficit of labor force and unemployment.

Initially, this direction of research came up as part of V. Leontiev’s model, when he applied method of input-output analysis and linear algebra for the formalization of US economy in the 30s of XX century. On the basis of Leontiev’s model there was created so called “Chase Model” by Robert Chase [1], which is used by USA in forecasting demand for workforce.

The U.S. Department of labor makes forecasts of employment according to six interrelated steps, while six interrelated elements of the model are being executed. The result of each step forms the input in further step. The methodology of the model represented in Handbook of methods of U.S. Bureau of Labor Statistics [2].

The most known analog of US model in Russian Federation is V. A. Gurtov’s model created for forecasting demand and supply at labor market [3]. Formalization of interaction of economics and labor market in this model based on classic CES-function and Cobb-Douglas production function. Supply at labor market directly depends on system of education of Russian Federation.

New complex of mathematical models of labor market is being created currently through join efforts of the company IBS Expertise and Plekhanov Russian Academy of Economics for Ministry of education and science of Russian Federation. The main difference of the complex from other analogs is the mathematical technique — system dynamics. Moreover, such natural dynamic processes as changing economic activities and requalification by workers during seeking new job have been taken into account.

In actual fact the article aimed at description the part of the complex responsible for supply at labor market — Model of state and moving of workforce in the region. The primary aim of the model is to show the dynamic of number and structure of employed people. This information will help government to see what happens with labor market in future and develop appropriate decisions to improve.

2 System dynamics

The model is based on system dynamics which means that behavior of model is described by a system of interrelated linear differential equations with certain initial conditions. Dynamic modeling, which is one of economic and mathematical methods, has significant differences from all methods of modeling. Static model forecasts against the dynamic one does not consider changes over time. Modeling of interrelations of variables is relevant within certain period of time. One of the important features of dynamic modeling is the division of resources on flows and their accumula-
tion in the so-called stocks (the funds), such as stores, banks, etc., as well as the impact velocity characteristics of parameter changes on the behavior of the object as a whole.

The method of dynamic simulation was designed to study social and economic processes and changes in state at time intervals. At the same time every moment of all the processes and states depend on the model structure and the entire prehistory of the object. A very important feature of dynamic modeling is the possibility of implementing the model continuous processes. Static methods do not detect rapid changes in the parameters, which leads to appreciable errors in the results. Modeling of continuous processes also detects abrupt changes, and this increases the accuracy of research.

3 General structure of the model

First of all let’s consider one region labor market model. Model includes such vital factors influencing number and structure of workforce as following:

1. Aging of workforce.
3. Number of schoolchildren.
4. Number of people studying at institutions of professional education.
5. Moving of workforce between economic activities.

If worker has changed his place of work and another speciality has been required at new place then it is assumed that the worker has changed his speciality too. On the Fig. 1 you can see general structure of one region model of labor resources movement.

'School' in Fig. 1 contains quantity of schoolchildren of each sex and in each school year. Every simulation year schoolchildren move to next year of study, graduate from last grade level and die in accordance with death rate in their age group. In some regions there can be a percentage of people which do not finish or do not enter school at all. For this reason model support flows from general education to stock of unemployed people.

The process of going to school (1st grade) becomes reasonable only if prognostic period of simulation greater than number of school years plus years spent on studying in institutions of professional education. In this case number of first formers will influence on labor market during simulation. Obviously, that if prognostic period, for example, is less than 5 years, consideration of schoolchildren number as a factor influencing on labor market is not justified.

'Professional Education' stock keeps information about number of people who are studying in institutes of professional education of every speciality, year of study and sex. Moreover, levels of professional education like initial, middle and higher can be added to the structure of the stock if it is applicable for concerned country. List of specialities in model corresponds with official classifier used in a country.

Similar to processes at 'School' students move to next year of study, graduate, die and leave institutes for some reasons (according to statistics). Governments can partly or completely control admission quotas by financing, restrictions, etc. Model makes it able to regulate the quantity of funded places at different specialities and watch changes in labor market it can result in.

'Labor Market’ stock (Fig. 1) has sections of specialities, economic activities, age groups and sex. Economic activities can be the groups of businesses united in accordance with Statistical classification of economic activities in the European Community, or Global Industry Classification Standard, or any classification similar to them and used in particular country. Choice of appropriate classification depends on the form of available statistical data. Moving of workforce at labor market every simulation quarter is a complicated process which involves following components:

1. Mortality. Number of labor resources in particular age group decreases every quarter according to formula (1).

\[
\frac{dLE_a}{dt} = -LE_a \cdot D_{ta}, \quad a = 1 \ldots na, \quad (1)
\]

\(na\) — quantity of age groups,
$Dr_a^t$ - death rate in age group $a$, in time $t$. Shows the number of deaths of population in age group $a$, scaled to size of population per unit time ($dt$),

$L_E_a$ - number of employed people at labor market in age group $a$,

dt - unit time (quarter).

The value of death rate ($Dr_a^t$) during forecast period of the model is taken from simple linear trend model on the basis of available statistical information about previous years. Also, future values of $Dr_a^t$ can be made by experts.

2. Retirement. For estimation of number of people in labor market it is required to deduct retiring people according to statistics each period of simulation. Formula (2) shows changes in labor market because of retirement.

$$\frac{dL_E_{a,s}}{dt} = -L_E_{a,s} \cdot p_{Ret_{a,s}}, \quad a = 1 \ldots na, \quad s = 1, 2,$$

(2)

$na$ - quantity of age groups,

$L_E_{a,s}$ number of employed people at labor market in age group $a$ and sex group $s$,

$p_{Ret_{a,s}}$ probability of ending employment completely (retire) in age group $a$ and sex group $s$, scaled to $L_E_{a,s}$ per unit time (the value of $p_{Ret_{a,s}}$ is made by experts),

dt - unit time.

3. Aging. In the model it is the flow of some number of people from age group $a - 1$ to age group $a$ every year. The quantity of people moving from age group $a - 1$ to next age group every year equal to $1/\text{alim} \cdot L_E_a$, where $\text{alim}$ is the size of age group. Then, formula (3) shows the change in the number of employed people at labor market because of aging.

$$\frac{dL_E_{a,s}}{dt} = -\frac{L_E_a}{\text{alim}_a} + \frac{L_E_{a-1}}{\text{alim}_{a-1}}, \quad a = 1 \ldots na,$$

(3)

$na$ - quantity of age groups,

$\text{alim}_a$ - size of age group $a$,

$L_E_a$ - number of employed people at labor market in age group $a$,

dt - unit time (one year).

Such approach is correct only if the number of people in age groups is normally distributed, which is not true. For more accurate evaluation of number of people moving between age groups more refined statistical information about number of people in individual years of age, economic activities and specialities is required.

4. Change of speciality and economic activity on labor market. Every person has a possibility and the intention to change work. Change of work can happen with changing of economic activity, speciality of worker and with changing of economic activity and speciality simultaneously. The intention in model is formalized as a function where argument is ratio of wage at current place of work and wage at desired place of work. It is considered that information about average wages in sections of economic activities and specialities for employed people is available. The function of intention to change work presented in Fig 2.

The data points A,B,C,D in Fig. 2 must be assessed on the public opinion poll basis. Information about average wages in sections of economic activities and specialities for future period is made on the simple trend model basis. All probabilities of workchange because of wages ratio in model are united in one matrix (4).

$$WR = \begin{pmatrix}
wr_1^1 & wr_2^2 & \ldots & wr_{nea\cdot nse}^1 \\
wr_1^2 & wr_2^2 & \ldots & wr_{nea\cdot nse}^2 \\
\vdots & \vdots & \ddots & \vdots \\
wr_1^{nea\cdot nse} & wr_2^{nea\cdot nse} & \ldots & wr_{nea\cdot nse}^{nea\cdot nse}
\end{pmatrix}$$

(4)

$nea$ - number of economic activities,

$nse$ - number of specialities of education,

$(nea \cdot nse) \times (nea \cdot nse)$ - size of matrix WR.

The possibility of change work is represented in model in the form of special matrix $SP$ which consists of probabilities of change the work because of current speciality. The possibility of workchange depends only on education requirements at current place of work and at new place of work. For example, doctor can become a driver, but the opposite situation is not possible. The probabilities of such flows are contained in matrix $SP$ (5).
Flows between economic activities are regulated by the possibility to change speciality is identical. This means that in every economic activity the flows are represented by matrices \( SP \) which means that in every economic activity the flows are represented by matrices \( SP \). That is why, for calculative reason the flows between economic activities as it was mentioned earlier. That is why, for calculative reason the flows between economic activities as it was mentioned earlier.

Matrix (5) is evaluated on the expert poll basis. The process of changing work can be not only between specialities of worker in one economic activity, but also between economic activities as it was mentioned earlier. That is why, for calculative reason the flows between economic activities as it was mentioned earlier.

Final matrix which represents probabilities of changing the work because of education requirements, \( n_{ea} \) - number of economic activities, \( n_{se} \) - number of specialities of education, \( (n_{ea} \times n_{se}) \) - size of matrix \( ESP \).

Formula (3) shows the differential equation for the process of changing work by employed people at labor market stock using the matrix (7).

\[
\frac{dL_{ea,se}}{dt} = \sum_{i=1}^{n_{ea} - n_{se}} L_{ea,se} \cdot r_{q_{i}^{ea,se}} - \sum_{i=1}^{n_{ea} - n_{se}} L_{ea,se} \cdot r_{q_{i}^{ea,se}}
\]

\( i = 1, \ldots, n_{se}, n_{se} + 1, \ldots, n_{se} \cdot 2, n_{se} \cdot 2 + 1, \ldots, n_{se} \cdot n_{ea}, \)

\( n_{ea} \) - number of economic activities, \( n_{se} \) - number of specialities of education, \( L_{ea,se} \) - number of employed people at labor market in economic activity \( ea \) and with speciality \( se \), \( rq \) - element of final matrix of probabilities of change the work (7).

\[ SP = \begin{pmatrix}
sp_{1}^{1} & sp_{1}^{2} & \cdots & sp_{1}^{n_{se}}
sp_{2}^{1} & sp_{2}^{2} & \cdots & sp_{2}^{n_{se}}
\vdots & \vdots & \ddots & \vdots
sp_{n_{se}}^{1} & sp_{n_{se}}^{2} & \cdots & sp_{n_{se}}^{n_{se}}
\end{pmatrix}
\]

\( n_{se} \) - number of specialities of education, \( n_{se} \times n_{se} \) - size of matrix \( SP \)

\[ ESP = \begin{pmatrix}
SP_{1}^{1} & SP_{1}^{2} & \cdots & SP_{1}^{n_{ea}}
SP_{2}^{1} & SP_{2}^{2} & \cdots & SP_{2}^{n_{ea}}
\vdots & \vdots & \ddots & \vdots
SP_{n_{ea}}^{1} & SP_{n_{ea}}^{2} & \cdots & SP_{n_{ea}}^{n_{ea}}
\end{pmatrix}
\]

\[ SP_{1}^{1} = \ldots = SP_{n_{ea}}^{n_{ea}} = SP \] - matrices of probabilities of changing the work because of education requirements.

\( n_{ea} \) - number of economic activities, \( n_{se} \) - number of specialities of education, \( (n_{ea} \times n_{se}) \) - size of matrix \( ESP \).

4 Main realization problems

The first problem which the programmer faces is high dimension of the model. For instance, if number of economic activities is near 15, number of specialities of education is near 25 and there are three levels of professional education in the region then the dimension of matrix (7) is \( (15 \cdot 25 \cdot 3) \cdot (15 \cdot 25 \cdot 3) = 1265625 \) elements. All elements are recalculated every iteration and it essentially slows down the simulation. The disadvantage of system dynamic tools in AnyLogic is that in actual fact they make some needless work and it is hard to optimize calculations for user. It makes the builder of the model use lower levels of programming like writing functions in Java code, but in that case the usage of AnyLogic is under doubt. The time of simulation of the model written in Java code or any other language becomes acceptable.

Another complication is huge amount of statistical data required for the model. Some information such as average wage of person working in certain economic activity and having certain speciality can be absent at all. In that case there are several ways: expert evidence, some crude estimation or public opinion poll. The best option is public opinion poll, but to get representative sample when dimensions of the variables of the model is so large is too expensive.

References:
