

Modeling the Choice of an Optimal Educational Trajectory in the Conditions of Digital Transformation of the Economy

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Abstract: The processes of transformation of the modern economy taking place in recent decades encourage researchers to determine the place of higher education in general and of sets of educational programs in particular, in the new conditions of the educational services market. In the context of significant changes in the processes of market structures interaction, employers are forced to impose new requirements on university graduates, whose qualifications should be relevant to the current market. Since the university in this case is an intermediary between enterprises and skilled labor, its goal is to solve the shortage of personnel with a level of training that meets the new objectives of employers in the regional labor market. In these conditions, optimizing recruitment of students for the areas necessary for the market becomes relevant. To solve these problems, the following tools can be used: identifying value orientations and incentives for applicants in the process of choosing bachelor's degree programs, and admission of master's degree applicants who have shown an inclination for professional activity related to their undergraduate degree field. Thus, there is a need to study the applicants' educational trajectories in relation to their economic incentives, such as the amount of expected income after graduation. The method of this study combines an agent-based model with econometric modeling to determine the maximum expected salary after graduation. The first stage of modeling involves the use of an econometric model to adapt students' educational trajectories to their preferences. At the second stage of modeling, an agent-based model is used, which allows determining the behavior of students within the overall sample. To determine the probability of a student changing their educational trajectory, a fuzzy logical model was developed.

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Keywords: dynamic games, behavioral economics, dynamic model, higher education, regional labor market, agent-based modeling, educational trajectories.

1. INTRODUCTION

Higher education has faced serious changes in the environment that surrounds universities in Russia and around the world. These changes led to the emergence of many challenges for higher education institutions. The choice of a development strategy with a focus on improving the university's competitiveness and financial stability becomes vital in the new conditions (Carnoy M., Froumin I., Loyalka P.K. & Tilak J.B.G., 2014). In this regard, it is necessary to provide an up-to-date educational offer in accordance with the requirements of the market, as well as the implementation of the educational process with the possibility of choosing an optimal educational program for applicants. Additional driving factors for ensuring the university's competitiveness can be fostering research activities, the level of internationalization, and the admission of talented students who are interested in research activity.

The wide availability of higher education for potential students leads to such large-scale problems as a decrease in the quality of education provided by higher education institutions, different sets of disciplines within similar educational programs depending on the university; a mismatch between the demand for highly qualified professionals in the labor market and the offered degree courses, as well as an insufficient level of relevant knowledge among graduates who are in demand by employers. In addition, worth noting is the significant influence of the positions of universities in various ratings on the formation of adaptive and popular educational trajectories that meet the labor market demand.

The study of the economics of higher education in terms of the economic analysis of preferences is an urgent research objective. Many researchers consider the analysis of the choice of profession by applicants as an important component

of the process of improving the functioning of universities. There are studies that consider the dependence of the expected income after graduation on education in various fields of study (Carnoy M., Froumin I., Loyalka P.K. & Tilak J.B.G., 2014).

The choice of education by young people is influenced by both the education system and the public finance sector, through the number of state-funded places, tuition subsidies and scholarships. It should be noted that the national specifics of education funding significantly affect the choice of the degree field. The works of several researchers focus on the analysis of students' personal characteristics relationship, and attempt to assess the future benefits of higher education (Bachan R., 2014).

2. RESEARCH METHODS

In the last decade, the debate about whether university graduates' training meets the needs of the labor market has not subsided. The issue of the mismatch between jobs and university degree fields is discussed by experts in the field of higher education in the context of oversupply of "economists and lawyers" in the labor market, as well as a more in-depth issue: what are the necessary sets of competencies for young professionals and what is the impact of the educational experience at university on the starting salaries of university graduates. The solution of the fundamental research objective of identifying the reasons for the mismatch between graduates and the labor market requirements, the analysis of university graduates' educational, professional and career trajectories includes consideration of the following contradictions concerning the balance of the higher education system: the labor market, evaluation of the quality of the university's educational programs, the effectiveness of its graduates' employment, as well as their starting career positions.

Hypotheses about the discrepancy between the university educational programs and the needs of the labor market are put forward by Němec J. (Němec J., 2013), Hennemann S., Liefner I. (Hennemann S., Liefner I., 2010), O'Leary N., Sloane P. (O'Leary N., Sloane P., 2016). They note that supply exceeds demand, i.e. there are more graduates than the market needs (Research of Long-Term Forecasting).

In the process of obtaining a bachelor's degree, students mainly master basic knowledge and skills that form, first of all, general professional competencies. However, employers need young professionals who possess specific professional knowledge and skills that allow them to successfully participate in the modernization of modern production. The gap between the skills acquired at university and the skills required by employers is noted in the works of Cranmer S. (Cranmer S., 2006), Davies L. (Davies L., 2000), Finn D. (Finn D., 2000), Lindsay C. (Lindsay C., 2002).

However, in the current context of developing the higher education system and its connection with the labor market, serious changes are taking place in approaches to university training, as well as further adaptation to the labor market. Such a transformation is caused by (a) easy access to higher

education, when it can be obtained for a fee, (b) the influence of the actor's behavior frames on the choice of education, (c) the transition from elite to mass education, accompanied by a complex of problems.

When studying the contribution of the university to the success of graduates, three questions are highlighted related to the topic of our study. The first one is considering the value of introducing institutional research practices in universities, relying primarily on the Western experience of their implementation in universities. In the process of studying the needs, opinions, assessments of target audiences, including graduates, internal university research in Western practice covers a range of issues related to managerial decision-making and university activity planning (Knight W.E., 2010): funding crisis, competition for student learning efficiency, the need for effective management of various processes in a particular field of activity (educational, research), etc. In this sense, they are considered by the university management and other internal target audiences as a necessary condition that allows the university not only to survive, but also to improve its position in the market of higher education services.

The most common form of feedback is sociological research (polls), and according to the results of (Kidd W., Czerniawski G., 2011), this form of institutional research is one of the important mechanisms that facilitate the involvement of students and graduates in changing the educational process, or increasing loyalty due to repeated return to the university for further education, for joint development projects, etc.

The survey of graduates in different countries is carried out in two formats: (1) a continuous centralized survey based on data from tax authorities (for example, Denmark - an integrated database of labor market research (IDA) - the career histories of all graduates are tracked, as well as personal characteristics - gender, education, work experience, etc.); (2) a partial survey of university graduates based on questionnaires of a certain sample: a classic sample database of Higher School, collected by the US National Center for Educational Statistics.

The second one is determining the value of graduate studies for improving the quality of university educational programs and managing their changes in a timely manner, taking into account the needs of the regional labor market. Research practices among graduates are quite common in various subject areas (economics, sociology, marketing, management) both in foreign and Russian universities. An important aspect of these studies is the study of the specifics of the formal transition of graduates from the university to the labor market (Williford A.M., Moden G.O., 1989), in the context of which there is a special, more or less objective assessment of the educational opportunities provided by the university during the entire process of obtaining higher education, and other aspects of the university (the value of research, extracurricular activities, etc.). Thus, the results of graduates' employment immediately after graduation, their starting salary level, career positions, as well as subjective assessments of knowledge, skills and competencies acquired at university become extremely important for university

management. Thirdly, the experience is worth noting of conducting cross-sectional research among graduates as one of the groups of university stakeholders that has developed at Ural Federal University in connection with the need to manage the study of the process of forming the characteristics of its brand and reputation.

The approach used in this study involves a combination of an agent-based model with an econometric model of maximizing the students' expected salary. The first stage of modeling involves the use of an optimization model to adapt students' educational trajectories to their preferences. At the second stage of modeling, an agent-based model is used, which allows determining the behavior within a general sample of students, taking into account maximizing the impact of the learning process for each student. In order to determine the probability of students changing their educational trajectory, we used such parameters as: the number of possible promising directions, the probability of students receiving financial support from the government or university to pay for their studies, and an estimate of the students' total salary after graduation.

3. MARKET TENSIONS

Tension θ_k affects the development of the labor market, increases the risk of precarization and acts as a guideline for universities in the process of distributing state-funded places between educational programs. In general, tension is expressed by the following dependence:

$$\theta_k(t) = \frac{V_k(t)}{U_k(t)}, \quad k = 1, \dots, K, \quad (1)$$

where $V_k(t)$ is the number of vacancies in the market sphere corresponding to field of study k , $U_k(t)$ is the number of unemployed in the market area corresponding to field of study k .

The dynamics of the market are determined by the negotiation power of job applicants and the rates of reduction in the number of unemployed, as well as the rates of reduction of occupied and vacant jobs. Thus, unemployment in the market is determined by the function:

$$\begin{aligned} U_k(t + \Delta t) &= U_k(t) + U_k(t) \frac{m_k E_k(t)}{\alpha_k \cdot U_k^{\delta_k}(t) \cdot V_k^{\mu_k}(t)} \Delta t = \\ &= U_k(t) + \frac{m_k E_k(t)}{a_k(t)} \Delta t \end{aligned} \quad (2)$$

where $E_k(t)$ is the definition for those employed in degree field k , m_k is the flow of filled jobs in the system, a_k is the rate of increase/reduction of unemployed workers in the system.

At the same time, the dynamics of vacancies depend on the rate of job cuts in the employment process:

$$\begin{aligned} V_k(t + \Delta t) &= V_k(t) + V_k(t) \frac{m_k V_k(t)}{\alpha_k \cdot U_k^{\delta_k}(t) \cdot V_k^{\mu_k}(t)} \Delta t = \\ &= V_k(t) + \frac{m_k V_k(t)}{q_k(t)} \Delta t \end{aligned} \quad (3)$$

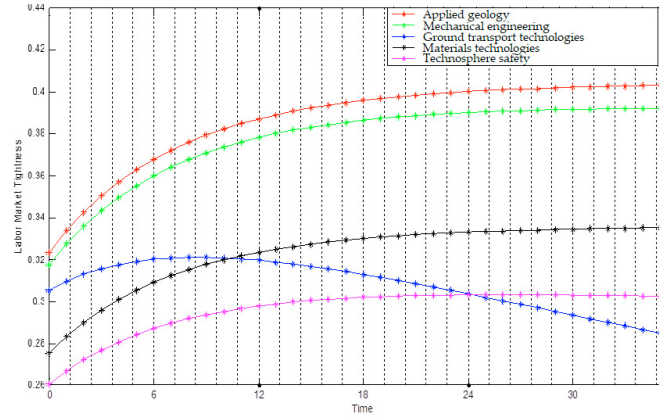


Fig. 1. Tension in the labor market for technical degree fields

4. OPTIMIZATION OF FINANCIAL RELATIONS BETWEEN THE UNIVERSITY AND STUDENTS

To optimize the university's financial and economic activities in the budget support department, market indicators are used as one of the benchmarks, including data on the ratio of vacancies and unemployed in the market in general areas of training. In this regard, it is possible to describe the process of allocating state-funded places necessary to meet the demand of the labor market in the conditions of digitalization, in a general way through synthetic parameter θ_k :

$$b_k = \frac{B}{k} \cdot \frac{\theta_k}{\theta_{av}}. \quad (4)$$

where θ_{av} is the average value of market tension for all areas of training, θ_k is the tension of the labor market for degree field k , k is the number of degree fields in the labor market, B is total number of state-funded places at the university.

This parameter is one of the key ones, along with the cost of training and the demand for a degree field in the labor market when applicants choose training areas. When constructing the model, we rely on the provisions of behavioral economics in terms of the predominant role of economic factors in the selection process. At the same time, the applicant in the model acts as an agent and is guided by the provisions of pure economic rationality.

5. MODELING THE ECONOMIC FEASIBILITY OF CHOOSING THE AREA OF TRAINING

The model assumes interaction between different data sets at the first stage of modeling. Initially, we have a fixed number of applicants a_j , represented as a dataset (row-matrix) $H_{h \times 1} = (a_j)_{h \times 1}$ containing their personal information. Each entrant is characterized by their own set of characteristics like the exam scores presented in the $E_{h \times n} = (e_{ji})_{h \times n}$ dataset. At the

same time, we analyze a dataset $Z_{n \times m} = (z_{is})_{n \times m}$ of exam packages which contains the information about fixed packages and includes different exams on the lines and packages in the rows. The dataset $F_{h \times m}$ depends on the general dataset of exam packages $Z_{n \times m} = (z_{is})_{n \times m}$ and on the dataset of exam scores $E_{h \times n} = (e_{ji})_{h \times n}$. This dependence is reflected in the expression:

$$F_{h \times m} = (f_{gs})_{h \times m} = \begin{cases} 0, & \text{if } e_{gi} = 0 \text{ or } z_{is} = 0 \\ E_{h \times n} \times Z_{n \times m}, & \text{if } e_{gi} > 0 \text{ and } z_{is} > 0 \end{cases} \quad (5)$$

During the initial analysis of the possibility of enrollment, the applicant's compliance with the initial requirements of the training area is checked. To do this, the data on the exams and exam packages passed by the applicant, represented by dataset $F_{h \times m}$, are compared with the scores required for enrollment for the training area represented by a dataset $Q_{m \times l}$, where exam packages for different specialties (training areas and educational programs) are given - by the rows. The dataset $Q_{m \times l}$ is built considering that an applicant can be enrolled for a program with different exam packages. To do this, we add additional columns for each educational program where it is possible to take into account different exam packages (more than one) for enrollment. As a result, we obtain the dataset $D_{h \times l} = (d_{gk})_{h \times l}$, which characterizes, among other things, the applicant's competitiveness:

$$D_{h \times l} = F_{h \times m} \times Q_{m \times l} = (f_{gs})_{h \times m} \times (q_{sk})_{m \times l}, \quad (6)$$

$$g = 1, \dots, h; s = 1, \dots, m; k = 1, \dots, l$$

In order to numerically assess the applicant's competitiveness at the enrollment stage, we will build a correlation for the applicant's initial indicators, exam scores required for admission and tuition fees set by the university. The assessment of the cost of training (cv_k) will be variable, depending on the applicant's initial characteristics, the availability of state-funded places and the chosen degree field (specialty):

$$cv_k = \begin{cases} 0, & d_{gk} > X_k, b_k > 0 \\ co_k, & Y_k < d_{gk} < X_k \end{cases} \quad (7)$$

where X_k is the admission score for a state-funded place, Y_k is the minimum exam score required for enrollment, co_k is the tuition fee for each specialty k .

In terms of pure rationality, those applicants who have confirmed their compliance with the requirements of the training areas, will strive to maximize their return from education, which is especially important in the context of the digital transformation of the economy. Under these conditions, applicants will choose the area of training that is optimal for them from an economic point of view (Tarasyev A.A., Agarkov G.A., Ospina Acosta C.A., Koksharov V.A., 2018).

To do this, the cost of training for the entire training period is estimated. In case of state funding, the cost of training is zero, $c_k = cv_k = 0$. Otherwise:

$$c_k = \sum_{t=0}^{T_1} cv_k(t) \quad (8)$$

where T_1 is the training period in years.

It is also necessary to estimate the expected income from working in the degree field. According to applicants' expectations, the payback period is three years. The applicant's expected income is described as:

$$w_k = \sum_{t=0}^{T_2} s_k(t) \quad (9)$$

where $s_k(t)$ is the expected annual income, T_2 is the payback period in years.

6. MAXIMIZING PROFITABILITY IN THE CONTEXT OF DIGITAL TRANSFORMATION OF THE ECONOMY

When choosing the area of training, the applicant aims to maximize the expected return on investment in higher education:

$$f = w_k - c_k \rightarrow \max \quad (10)$$

Thus, training areas that produce professionals for rapidly growing and developing areas of the labor market are advantageous for the applicant. The total number of applicants in different areas of training is expressed as follows:

$$r_k = \sum_{k=1}^n a_{jd_{gk}}, Y_k < d_{gk} < X_k \quad (11)$$

In the context of the digital transformation of the economy, applicants will give preference to specialties and training areas related to IT innovations, digital transition, development and implementation of information systems and technologies, business informatics and advanced system analysis.

From the university's perspective, the maximization of profitability from regulating the number of state-funded places in various areas of training is expressed linearly. In order to obtain optimal profitability, regular adjustment of the provision of training areas with state-funded places b_k is required. The function of usefulness for universities of the state-funded place distribution is the following:

$$u = \sum_k (b_k \cdot \alpha \cdot co_k) + \sum_k (co_k \cdot r_k) \rightarrow \max \quad (12)$$

Here the tuition fee is taken into account both in terms of the fees paid by the students, and in terms of state-funded places, where the number of places is multiplied by the corrected tuition fee, which is compensated by the government $\alpha \cdot co_k$. The coefficient α here depends on the specifics of labor market development and on the current socio-economic policy, therefore, for specialties that are in demand in the developing areas of the labor market, this coefficient will have a large value.

7. POSSIBILITY OF A STUDENT'S EDUCATIONAL PROGRAM CHANGE

To identify the probability of students changing their educational trajectory, a Mamdani-type fuzzy logical model was developed. In the model, the 3 input rules converge in setting the output variable of the probability of change. Thus, the number of possible promising directions is the first variable that influences the student's decision to change the program, the second variable is the probability of students receiving financial support from the state or university to pay for their studies, and finally, the last variable is the cost of tuition based on the analysis of the amount of money that students will receive as a salary when they complete their studies within the current educational program. The next step in the model is to establish ranges that can represent each of the model variables using natural languages.

According to the membership functions plots we have five scenarios, based on which we can describe the probability of educational program change from the very low to the very high probability.

Table 1. Functions for a student's switch between educational programs

Directions	Budget Support	Expected Salary	Possibility of Change
Low	Low	Low	High
		Medium	Normal
		High	Very Low
	Medium	Low	Normal
		Medium	Low
		High	Very Low
	High	Low	Normal
		Medium	Low
		High	Very Low
Medium	Low	Low	Normal
		Medium	Normal
		High	Low
	Medium	Low	Normal
		Medium	Normal
		High	Low
	High	Low	Normal
		Medium	Normal
		High	Low
High	Low	Low	Very High
		Medium	High
		High	Normal
	Medium	Low	High
		Medium	Normal
		High	Normal
	High	Low	Normal
		Medium	Normal
		High	Low

For the probability of a student getting budget support the situation is more equal, but the ranges overlap to a great extent. This means that this variable has more influence when the values are far away from the overlapping points. To estimate how much a student will earn, a more analytical

approach was used. Since there are not many vacancies with salaries above the average, for students who have just graduated from university, this range is considered high and, therefore, it is small compared to others. For the low and mid ranges, a similar process was used. For the output variable of the probability of change, 5 ranges were established, taking into account a big average range called "Normal" and other 4 equal ranges that overlap (Table 1).

During the modeling process we introduce ranges for the output variable, describing the probability of educational program change (Fig. 2). At the same time, we introduce the main rules of the fuzzy model. The students' decision in terms of this model depends on the preferred educational direction, the budget support possibility and the expected salary level.

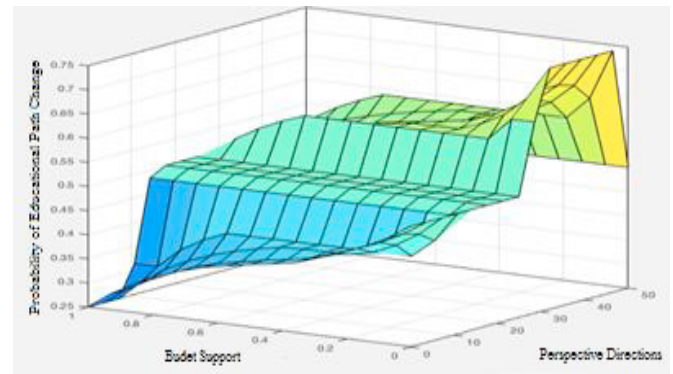


Fig. 2. Rules Surface

The Educational Program Change Probability varies between very high ($0.7 < VH < 1.0$), high ($0.6 < H < 0.9$), normal ($0.3 < N < 0.7$), low ($0.1 < L < 0.4$) and very low ($0.0 < VL < 0.3$) depending on the main model parameters. Within this model, we also establish a set of rules for the students' decision about changing their educational program.

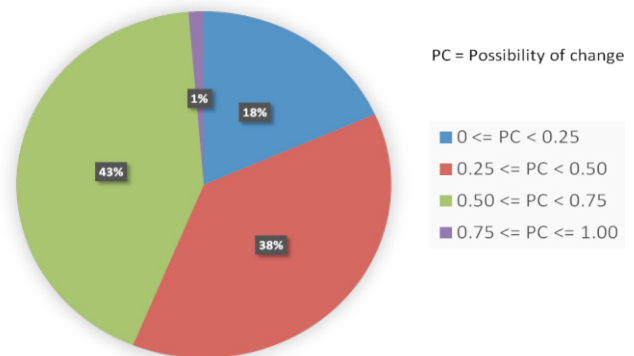


Fig. 3. Possibility of a student's educational program change

Some of the results obtained using the fuzzy logic model are presented in figure 3. According to the results, 82% of all students have the possibility to change their educational program, but as shown in the model of educational program optimization, it can be economically feasible for the students only in 31% of all cases. According to table 1, the most optimal educational programs are in Economics and Management, Public Administration and Entrepreneurship, and Military Technical Education and Security.

8. CONCLUSIONS

Ensuring competitiveness is a prerequisite for universities' effective educational activities. The factors that stimulate the development of higher education institutions may lie in various spheres of their functioning. The changing labor market and the economic situation of recent years determine the importance of effective performance of both research and educational functions of universities. The basis for competitive and up-to-date student training consists mainly in optimizing student admissions in the areas necessary for the market. In these conditions, there is a need to study the incentives and behavioral mechanisms that influence the applicants' choice of educational trajectories, which makes it possible to identify the advantages of the university's educational policy in terms of planning the level of investment in human capital. Analysis of a sample of Ural Federal University students showed that in the process of optimizing educational trajectories, the most significant factors are expected income after graduation (22%), reduced tuition fees or the opportunity to receive state subsidies (12%). A detailed study of the choice of educational trajectories by students can be considered the basis for improving the university's educational process. Another aspect of studying the process of choosing educational trajectories by applicants, students and graduates is ensuring the improvement of the quality of education, the actualization of educational programs and areas of training.

The applied fuzzy logic model describes the probability of a student changing their educational trajectory. The model also allows analyzing the impact of students' choice of an educational trajectory on the functioning of regional economic sectors. The probability of changing the educational program in the current model varies between five levels and depends on the number of promising areas of graduation for students, the possibility of state budget support for each student and the expected salary level after graduation. For further research, we plan to expand the model by analyzing social and personal characteristics. The presented approach that consists of a combination of an agent-based model with an econometric model for calculating optimal educational programs, has been tested, which allows us to draw the following conclusion: economic incentives have the most significant influence on the choice of an optimal educational trajectory. This provision can be used by higher education institutions to improve their educational offer.

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