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Оценка индивидуальной конкурентоспособности участников рынка труда, основанная на теории латентных переменных

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Реферат. В статье предлагается оригинальная модель к оценке степени конкурентоспособности, успешности субъектов на рынке труда. Авторы указывают, что универсальный комплексный показатель конкурентоспособности индивида на рынке труда не выделяется. Однако оценку такой конкурентоспособности можно достаточно точно провести на основании некоторых переменных, различающихся для внутреннего и внешнего рынка труда. В основе предложенного подхода лежит модель оценивания латентных переменных по методу Раша. Модель оценивания позволяет получать объективные обобщенные оценки конкурентоспособности субъектов по линейной безразмерной шкале на основании частных оценок по выбранным критериям. Произвольный выбор критериев позволяет применять модель в различных сегментах рынка труда. В работе приведено математическое обоснование модели, методология выбора оценочных критериев, методика получения оценок в среде MS Excel, проанализированы свойства полученных оценок и проведено их сравнение с оценками, полученными по классическим методикам. Предложенная авторами модель позволяет ввести в качестве переменной любую количественную характеристику конкурентоспособности после анализа факторов, влияющих на нее. Эти факторы в своей количественной оценке станут критериями модели, точность же оценки при этом не изменится.

Ключевые слова: рынок труда, конкурентоспособность индивида, сегмент рынка труда, математическая модель, латентная переменная, метод Раша

Labour market participants' competitiveness assessment based on latent variables theory

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Summary. The article suggests innovative model for assessment of labour market subjects' competitiveness, or successfulness. The authors state that general complex indicator for individual competitiveness within the labour market cannot be identified. Instead, precise enough assessment of such competitiveness can be based on some variables, though different for in-house and external labour market. The model of latent variables' assessment based on Rasch's method was selected as the base for the suggested method. The assessment model gives unbiased generalized values of subjects' competitiveness on the linear non-dimensional scale based on the partial estimates of the selected criteria. The free choice of these criteria allows the model's appliance for various labour market segments. The article demonstrates the mathematical grounding for the model; methodic of the assessment criteria selection; the way of assessment performance using MS Excel. It also analyses the features of the obtained estimates and shows their comparison with the estimates obtained by traditional methods. The model suggested by the authors can introduce any quantitative parameter of competitiveness as a variable after analysis of the factors affecting it. The quantitative estimates of these factors become the model's criteria, but the assessment precision does not alter.

Keywords: labour market, individual competitiveness, labour market segment, mathematical model, latent variable, Rasch's method

Introduction

Here we suggest innovative approach to assessment of qualitative indicators describing the degree of success of labour market subjects. This approach is based on mathematical model of latent variables, particularly, on Rasch's method developed in the second half of the twentieth century and recently often applied for similar problems in various fields of science.

Problem statement and the way of its solution

Based on the results of our research we can state, that general complex indicator for quantitative assessment of individual competitiveness within the labour market cannot be identified either in general or for specific individual cases. However, precise enough assessment of such competitiveness can be based on some variables, though different for in-house and external labour market. The task was to obtain unbiased estimation of individual competitiveness parameter for an arbitrary subject within a certain labour market segment.

For such tasks in various fields of science researchers recently use mathematic approach based on latent variables' theory. Mathematics and statistics define the term 'latent variable' (or implicit variable) as such a variable that cannot be directly measured. Such variables may be estimated only by

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means of some mathematical models as the functions of a number of observable variables. These directly measurable observable variables are called indicator variables and the estimation of the latent variables is performed on their basis.

In our case the parameter describing an individual's competitiveness within the labour market is typical latent variable. In order to measure it one uses measurable indicator variables describing the latent one from some or other point of view.

For the external labour market such variables include the degree of individual unemployment risk and its duration as well as wealth achieved through employment. For the labour market within a company the size and structure of the labour remuneration may also be an indicator of competitiveness, but this parameter is often distorted by the factors external to the employer. We accept that the more relevant indicators are the duration of employment within the company and the speed of the vertical career.

A certain individual at the end of his working life can analyze his competitiveness in retrospect and estimate the stated parameters. However, there is almost no practical use in such analysis because of volatility of all external factors and the ways an economic individual adapts to them. In other words, it is easy to find out what made the father successive but this knowledge cannot help the son as the latter lives and acts under completely different conditions. Therefore, the need for prospective individual competitiveness assessment is great in the labour market, and this can be performed based on the forecast of the quantitative success parameters we have indicated.

After studying the designed methods for competitiveness assessment for both economic subjects – companies and individuals, we came to the opportunity to suggest our own method of estimation of the individual's labour market competitiveness parameters based on the latent variables' measurement theory.

The first logically completed theory for latent variable measurement was latent-structural analysis [1]. However, latent-structural analysis had considerable limitations in terms of practical appliance, and by now it is used in few scientific areas like sociology, psychology, etc.

The pioneer of the contemporary theory of latent variables' measurement is Georg Rasch. Rasch's model [2–4], unlike the other approaches to latent variable's measurement, obtains the estimates in a linear scale and in non-dimensional units called logits. It presents a number of advantages:

1. Rasch's model allows to transform the indicator variable measurements in dichotomous, attributive, or continuous scales into linear measurements, thus enabling qualitative data adaptation for qualitative analyzing methods.

2. As the measurement scale for Rasch's model is linear and non-dimensional, whole wide variety of statistic procedures and data processing methods can be applied to the obtained results.

3. Subject's latent parameter estimates do not depend on the indicator variables, but are the individual characteristics of each subject.

4. Alone with the subject's estimates the model provides the estimation of the features of the indicator variables' themselves, and these estimates also do not depend on the set of the estimated subjects, but are their individual characteristics.

5. Due to rather simple structure of the estimation model there are convenient computing procedures for obtaining the estimates which may be implemented for PC using available software.

If we use Rasch's model to assess subjects' competitiveness within the labour market based on certain estimation criteria (indicator variables), this helps to fulfill the achieve the following objectives:

1. To obtain unbiased estimation of competitiveness for each subject within a certain group on a linear interval scale. Such estimates allow ranging of these subjects in the group which, in its turn, enables the researcher or manager to make some decisions concerning, for instance, personnel improvement, employment, risk-management, etc.

2. To obtain the criteria feasibility estimates based on the whole group of subjects, enabling analysis of the general conformance to some or other criteria and requirements, for example, in the area of professional aptitude, educational standards, motive and stimuli for the whole group which can be a company's staff, a university students, etc.

The structural scheme of the model's performance is shown in the figure 1.

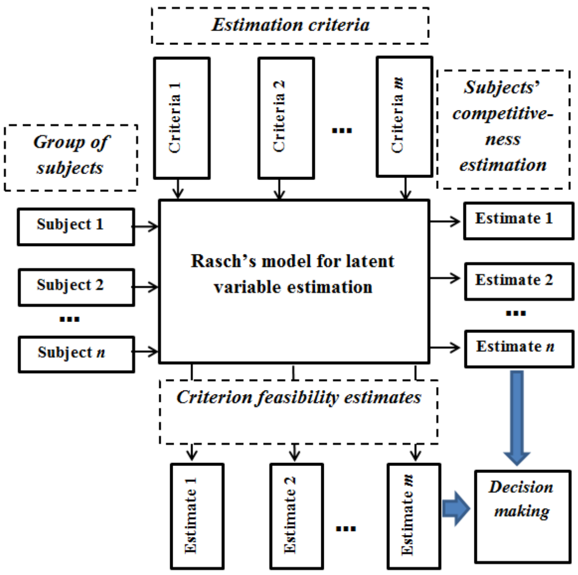

Figure 1. The structural scheme of the model for individual's competitiveness assessment

Let us see its appliance for an example. Suppose, these is a company in need of recruiting of one or more employees. Each candidate is assessed individually alone with the others and in accordance with the selected criteria. The results are processed using Rasch's method. As a result every participant gets certain complex estimate of his suitability for the position. Based on these estimates one may make the decision to include the candidates into the company's staff or replacement of the already hired people. Simultaneously, we obtain the estimates of the criteria feasibility, and if some of them demonstrate low values, this may bring about some measures aimed at improvement of the general situation with these criteria.

As we can see from the general structure of the model, its key point is the selection of the estimation criteria.

Estimation criteria selection

As an example let us choose such characteristic of an individual's competitiveness as his personal risk of unemployment. First of all we need to detect the factors affecting this characteristic. According to the figure 2, these factors can be divided into three groups.

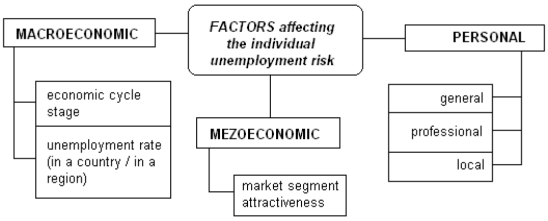

Figure 2. Factors defining the individual unemployment risk

Macroeconomic factors consist of the influence of the macro environment upon the labour market, its specific segment and particular individual. First of all, they include two factors: the observed stage of the economic cycle (out of the existing four stages we are most interested in two – growth and depression as they demonstrate the clearest dynamics of indexes) and the unemployment rate estimated based on the ILO procedure at the national or regional level. Taking into account only two stages of the economic cycle, we may suggest to unite the two stated criteria into one – 'dynamics of the unemployment rate' calculated as the difference between the unemployment rate for the current and previous period. During depression this difference would take negative value, and during growth – positive value.

Mezoeconomic factors describe a certain segment of the labour market available for an individual or a group of them, this segment being limited with just one or a number of characteristics such as region, profession, branch of economy, etc. The key factor here is segment attractiveness, or the level of competition within it which, in its turn, cannot be directly measured quantitatively, as, even though one can define the number of vacancies existing at a certain moment of time, the change of this parameter in time also should be taken into consideration. Besides, it is impossible to find the exact number of applicants for those vacancies, as not all of them undertake any activities to get the position. We suggest to use the following indicators as the criteria for this factor:

i) ratio of the average wage within the market segment of within the region or national economy as a whole, per cent;

ii) the share of students of professional education organizations studying to get the professions useful for this segment, in the total number of students at the moment, per cent.

And finally, the main group of factors are personal factors. We name this group as the main one not because the importance of their influence is greater than that of the others groups. For many situations such statement would be completely wrong. However, the first two group of factors affect the results of individuals' comparison when we consider indirect competitors, for instance, applicants for similar positions in different companies, regions or countries, fields of business, etc., in other words, acting within different segments of the labour market. But in case of comparison within the same segment all macro – and mezoeconomic criteria are the same for all participants, and the individual competitiveness is defined by the factors of the third group only.

The quantitatively measurable criteria for our example, where the applicants aspire the same position in the same company, we suggest those shown in the table 1.

Table 1.

Criteria, units, and scales for personal factors measurement

Criterion	Estimate	Scale, units
1	2	3
Educational level – 'K1'		Points, 1 to 10
	Master, specialist	10
	Bachelor	9
	Secondary vocational	7
	Elementary vocational	5
	Basic (no professional training)	1
Education compliance to the position profile – 'K2'		Points, 1 to 5
	Exact compliance	5
	Major	4
	Field of study	3
	No compliance	1
Working experience with the same or similar job description – 'K3'	0, 1, 2… n	Years
Unemployment duration up to the present moment – 'K4'		Points, 1 to 5
	Never worked before	2
	Over a year	3
	Over three years	1
	Less than a year	5

Continuation of Table 1

1	2	3
Age – ‘K5’		Points, 1 to 5
	Younger than 30	4
	30–40	5
	40–50	3
	Older than 50	1
Capacity degree – ‘K6’		Points, 1 to 10
	Employable	10
	Pensioner	4
	Youngster	1
	Disabled	5
Demographic criterion – ‘K7’		Points, 1 to 10
	Single man	9
	Married man	10
	Married man with little child/children	6
	Single woman	10
	Married woman	8
	Married woman with child/children	5
	Married woman with little child/children	1

Let us stress out, that the demonstrated list of criteria is selected for the abstractive example. If a specific vacancy is studied, the model admits of replacement or addition of any number of criteria without reduction of adequacy or accuracy of the assessment. The scales and units for the criteria also can be arbitrary: interval or semi-interval scales; natural or analogue quantities; dichotomous or polytomous data.

Mathematical justification of the model validity

Let us consider the mathematical justification of the Rasch’s model validity for the given problem.

Suppose there are N subjects whose competitiveness within the labour market is to be estimated: A_1, A_2…, A_N and L criteria for the estimation: K_1, K_2… K_L. Let U_{ij} denote the estimate of the i-th subject based on the j-th criterion. As stated before, these estimates can be of various nature and dimensionality. To bring the estimates to the same scale one is to apply normalization procedure. It means that the estimates U_{ij} are converted to the scale from 0 to 1 by means of linear operators. Let u_{ij} denote normalized estimates obtained using the formula:

$$u_{ij} = \frac{U_{ij} - U_{\min}}{U_{\max} - U_{\min}}, \qquad (1)$$

where $U_{\max}$ and $U_{\min}$ – maximum and minimum values for the estimates among the possible ones for the given criterion, generally $U_{\min} = 0$ and the normalization formula specializes $u_{ij} = U_{ij}/U_{\max}$.

Suppose the estimate of the n-th subject based on the j-th criterion is u_{nj}. Then the simplest way to assess the competitiveness of this subject is the additive method as the sum of the partial estimates:

$$X_n = \sum_{j=1}^{L} u_{nj} , \qquad (2)$$

which is usually done. However, such estimates are not responsive enough, non-linear, they depend on the set of assessment criteria and the multitude of the subjects. All these deficiencies are eliminated in Rasch’s method for latent variables estimation which is demonstrated hereafter [5–7].

For its reasoning we apply probabilistic approach. Let us consider the possible estimates of the subjects of numbers n and m. Let P_{nj} denote the probability or measure of the situation that n-th subject suits some abstractive employer in terms of j-th criterion. The term ‘suits’ should be interpreted as the presence of the possibility that the employer may choose this subject, that is there is probability but not the guarantee of such choice. Thus, the subject is acceptable for the employer. Then, the probability of the same subject’s being unacceptable for the employer equals (1-P_{nj}). Let us accept the same suggestions for the m-th subject.

Let us denote: N_{11} – the number of criteria based on which the both subjects suit the employer; N_{10} – the number of criteria based on which only the m-th subject suits the employer; N_{01} – the number of criteria based on which only the n-th subject suits the employer; N_{00} – the number of criteria based on which none of subjects suit the employer.

From the point of view of the said two subjects, only indicators N_{10} and N_{01} can be considered informative. In their turn, the indicators N_{11} and N_{00} do not form any idea about which of the subjects has better chance for employment. Parameter N_{10}, characterizing the degree of the A_m subject’s attractiveness, according to the probability multiplication theorem, being linearly proportional to the product probability P_{mj} (1-P_{nj}). Similarly, parameter N_{01} is linearly proportional to the product probability (1-P_{mj})P_{nj}. Thus, the formula defining the ratio of parameters N_{10} and N_{01}:

$$\frac{N_{10}}{N_{01}} \sim \frac{P_{mj}(1-P_{nj})}{P_{nj}(1-P_{nj})} . \qquad (3)$$

If we take infinite number of criteria L, it helps to find the difference of the estimates for the subjects n and m. As no limitations was imposed on the criteria, the obtained formula does not depend on any characteristics of the criteria themselves. Considering another subject with the number k, similar formula was obtained. The estimates ratio for the subjects remains the same. Consequently, we can write the following for criteria k and j:

$$\frac{P_{mj}(1-P_{nj})}{P_{nj}(1-P_{mj})} = \frac{P_{mk}(1-P_{nk})}{P_{nk}(1-P_{mk})}. \tag{4}$$

In its turn, this formula leads to the following:

$$\frac{P_{nj}}{1-P_{nj}} = \frac{P_{nk}}{1-P_{nk}} \cdot \frac{1-P_{mk}}{P_{mk}} \cdot \frac{P_{mj}}{1-P_{mj}}. \tag{5}$$

For practical use of the described method we need the results of the n and m subjects' competitiveness comparison to be unbiased. In its turn this requirement means the ratio of any number of the k and j subjects should be correct for any criteria. In order to provide for this requirement, the initial points for the comparative analysis were accepted as the estimates of some subject with 0 index, and some criterion with 0 index. Besides, unified measurement scale is required, uniting the competitiveness degree of the subjects and the importance (feasibility) of the criteria, the convenient initial point being the mentioned indicators with 0 index, which are considered equivalent. So, the value of the P_{00} parameter equals 0.5. Applying this, we come to the following formula:

$$\frac{P_{nj}}{1-P_{nj}} = \frac{P_{n0}}{1-P_{n0}} \cdot \frac{1-P_{00}}{P_{00}} \cdot \frac{P_{0j}}{1-P_{0j}} = \frac{P_{n0}}{1-P_{n0}} \cdot \frac{P_{0j}}{1-P_{0j}}. \tag{6}$$

It is necessary to note, that in the formula (6) the value $\left(\frac{P_{n0}}{1-P_{n0}}\right) = d_n$ – is the indicator of competitiveness of the n-th subject, which is his unique indicator, $\frac{P_{0j}}{1-P_{0j}} = \frac{1}{b_j}$ – is the value reciprocal to the feasibility, or importance degree, for the j-th criterion, which is the unique feature of this criterion. Thus, we get:

$$\frac{P_{nj}}{1-P_{nj}} = \frac{d_n}{b_j}. \tag{7}$$

On that basis, it is possible to calculate the probability of the situation when the j-th subject suits the employer comparing the applicants based on the n-th criterion. Such probability is defined by the ratio of a subject's competitiveness to the criterion's feasibility.

Using the formula (7) above, and having taken the logarithm of its part we get:

$$\ln\frac{P_{nj}}{(1-P_{nj})} = \ln\frac{P_{n0}}{1-P_{n0}} + \ln\frac{P_{0j}}{1-P_{0j}} = \ln(d_n) - \ln(b_j).$$

Denoting $\ln d_n = \ln\frac{P_{n0}}{1-P_{n0}} = \theta_n$, and $\ln\frac{P_{0j}}{1-P_{0j}} = \ln b_j = \beta_j$ we get:

$$\ln\frac{P_{nj}}{(1-P_{nj})} = \theta_n - \beta_j.$$

Which is equivalent to

$$\frac{P_{nj}}{1-P_{nj}} = e^{\theta_n - \beta_j}.$$

On that basis, renaming the indices for convenience we can calculate the probability P_{nj}:

$$P_{ij} = \frac{e^{\theta_i - \beta_j}}{1+e^{\theta_i - \beta_j}}. \tag{8}$$

These probabilities can be interpreted as normalized estimates of the subjects based on criteria u_{ij}.

The received formula is similar to Rasch's formula developed for estimation of latent variables [2].

In order of practical appliance of (8) we need to find the estimates of attractiveness of the subjects θ_i and feasibility degree of criteria β_j based on the known estimates of the subjects with criteria u_{ij}, obtained a posteriori.

If we consider the classic Rasch's model for latent variables estimation [1–3], there θ_i and β_j are found by maximum likelihood method (ML-method) [8]. However, such model requires the initial data u_{ij} to be only dichotomous, which means they can take only two values – 0 or 1. This does not suit the requirements described in this article, which demand that the data can adopt any value from arbitrary, including continuous range from 0 to 1. Due to this, in [9] it was suggested to apply the least square method, which use for similar problems is described in [5–7]: parameters θ_i and β_j of the model (8) are selected so that the sum of squared deviations of the empirical evidence u_{ij} from the calculated probabilities (8) is the least possible. Mathematically it comes to the optimization task:

$$S(\theta_i, \beta_j) = \sum_{i=1}^{m}\sum_{j=1}^{n}(u_{ij} - P_{ij})^2 = \\ = \sum_{i=1}^{m}\sum_{j=1}^{n}\left(u_{ij} - \frac{e^{\theta_i - \beta_j}}{1+e^{\theta_i - \beta_j}}\right)^2 \to \min. \tag{9}$$

Estimates θ_i and β_j, obtained from this model, will be measured in interval scales, the initial point for calculation being indeterminate. Zero reading of the scales can be selected so that all estimates are nonnegative. Then the optimization problem (9) will have the addition of normalization requirement:

$$\theta_i \ge 0;\ \beta_j \ge 0;\ i = 1, 2, ..., m;\ j = 1, 2, ...n. \quad (10)$$

The presented mathematical model for estimation (9) and (10) suggests, that all the criteria have the same importance and add equal contribution to the final estimation of subjects' competitiveness. If the criteria's importance varies, and their contribution to the final estimation should reasonably be proportional to their importance, then criterion weight shall be applied. Suppose the value w_j equals the weight of the j-th criterion. Suppose the weight varies along the scale between 0 and 1 (which is not necessary), and the bigger the weight, the greater contribution to the final estimation of subjects' competitiveness the criterion adds. To take the weights into consideration is minimization of the residual sum, each summand (9) shall be taken into account in proportion to its weight, and instead of (9), we get the optimization problem as follows:

$$S(\theta_i, \beta_j) = \sum_{i=1}^{m}\sum_{j=1}^{n} w_j \cdot (u_{ij} - P_{ij})^2 = \\ = \sum_{i=1}^{m}\sum_{j=1}^{n} w_j \cdot \left(u_{ij} - \frac{e^{\theta_i - \beta_j}}{1 + e^{\theta_i - \beta_j}} \right)^2 \to \min . \quad (11)$$

Solution of the optimization problems (9) and (10), or (11) and (10) may be performed using various software, for example, MS Excel with the help of customization Solver [8, 9]. Let us demonstrate the method of estimate calculation on some general example.

Competitiveness estimates calculation using MS Excel

To perform practical calculations and solution of the optimization problem one can use a variety of software, most available among them is MS Excel with customization Data Analysis [5, 6, 9]. To describe the method of the given problem solution let us consider some example.

For 10 subjects estimation of their competitiveness within the labour market is performed based on 7 criteria described in the table 1. Suppose each of them received some estimates of every criterion, as stated in the table 2. Besides, the decision was made to set different importance of the criteria and set weights stated in the same table.

Table 2.

The results of the subjects' estimation based on the criteria and the criteria's weights

Subjects	Criteria						
	К1	**К2**	**К3**	**К4**	**К5**	**К6**	**К7**
C1	5	3	5	2	4	10	5
C2	7	4	8	3	1	10	8
C3	1	1	12	1	3	10	10
C4	9	1	3	2	1	10	6
C5	7	3	0	3	5	1	9
C6	5	5	18	5	3	4	6
C7	7	4	0	2	1	10	1
C8	9	4	1	5	5	10	9
C9	10	1	0	2	3	10	8
C10	1	1	0	5	4	5	10
Weight	**0.8**	**0.7**	**0.8**	**0.6**	**0.7**	**0.7**	**0.5**

In order to apply Rasch's method to process the data of the table 2, it is necessary to perform normalization procedure in accordance with the formula (1). Normalized data for individual subjects' estimates are shown in the table 3.

Table 3.

The results of the normalized subjects' estimations based on the criteria

Subjects	Criteria						
	К1	**К2**	**К3**	**К4**	**К5**	**К6**	**К7**
C1	0.5	0.6	0.28	0.4	0.8	1	0.5
C2	0.7	0.8	0.44	0.6	0.2	1	0.8
C3	0.1	0.2	0.67	0.2	0.6	1	1
C4	0.9	0.2	0.17	0.4	0.2	1	0.6
C5	0.7	0.6	0	0.6	1	0.1	0.9
C6	0.5	1	1	1	0.6	0.4	0.6
C7	0.7	0.8	0	0.4	0.2	1	0.1
C8	0.9	0.8	0.06	1	1	1	0.9
C9	1	0.2	0	0.4	0.6	1	0.8
C10	0.1	0.2	0	1	0.8	0.5	1

Next we open an MS Excel book, feed the data in accordance to the figure 3 (the topmost table). Below the probabilities (8) are calculated. For this we dedicate the cells for the latent variables θ_i (range A17-A26) and β_j (range B16-H16). First of all, let us input some arbitrary data, for instance, 1, into these cells. For the calculations in accordance with the formula (8) into B17 we feed =EXP($A17-B$16)/(1+EXP($A17-B$16)) and then automatically spread it to the whole range of B17-H26. To calculate the summands of the formula (11) we feed into B29 to formula =B$13*(B17-B3)^2 and automatically spread it to the whole range B29-H38. The objective function itself (11), optimization of which is to be performed, is fed into the cell D40 as a formula =СУММ(B29:H38). The results of the data preparation for the spreadsheet are shown in the figure 3.

	A	B	C	D	E	F	G	H
1		Исходные данные						
2		К1	К2	К3	К4	К5	К6	К7
3	C1	0,5	0,6	0,28	0,4	0,8	1	0,5
4	C2	0,7	0,8	0,44	0,6	0,2	1	0,8
5	C3	0,1	0,2	0,67	0,2	0,6	1	1
6	C4	0,9	0,2	0,17	0,4	0,2	1	0,6
7	C5	0,7	0,6	0	0,6	1	0,1	0,9
8	C6	0,5	1	1	1	0,6	0,4	0,6
9	C7	0,7	0,8	0	0,4	0,2	1	0,1
10	C8	0,9	0,8	0,06	1	1	1	0,9
11	C9	1	0,2	0	0,4	0,6	1	0,8
12	C10	0,1	0,2	0	1	0,8	0,5	1
13	**Вес**	**0,8**	**0,7**	**0,8**	**0,6**	**0,7**	**0,7**	**0,5**
14								
15		Матрица вероятностей (8)						
16	θ / β	1	1	1	1	1	1	1
17	1	0,5	0,5	0,5	0,5	0,5	0,5	0,5
18	1	0,5	0,5	0,5	0,5	0,5	0,5	0,5
19	1	0,5	0,5	0,5	0,5	0,5	0,5	0,5
20	1	0,5	0,5	0,5	0,5	0,5	0,5	0,5
21	1	0,5	0,5	0,5	0,5	0,5	0,5	0,5
22	1	0,5	0,5	0,5	0,5	0,5	0,5	0,5
23	1	0,5	0,5	0,5	0,5	0,5	0,5	0,5
24	1	0,5	0,5	0,5	0,5	0,5	0,5	0,5
25	1	0,5	0,5	0,5	0,5	0,5	0,5	0,5
26	1	0,5	0,5	0,5	0,5	0,5	0,5	0,5
27								
28		Слагаемые целевой функции (11)						
29		0	0,007	0,039506	0,006	0,063	0,175	0
30		0,032	0,063	0,002469	0,006	0,063	0,175	0,045
31		0,128	0,063	0,022222	0,054	0,007	0,175	0,125
32		0,128	0,063	0,088889	0,006	0,063	0,175	0,005
33		0,032	0,007	0,2	0,006	0,175	0,112	0,08
34		0	0,175	0,2	0,15	0,007	0,007	0,005
35		0,032	0,063	0,2	0,006	0,063	0,175	0,08
36		0,128	0,063	0,158025	0,15	0,175	0,175	0,08
37		0,2	0,063	0,2	0,006	0,007	0,175	0,045
38		0,128	0,063	0,2	0,15	0,063	0	0,125
39								
40	Целевая функция (11):			5,909111				

Figure 3. Input data for MS Excel

Then we call up MS Excel customization Solver, feed in the customization parameters according to the figure 4.

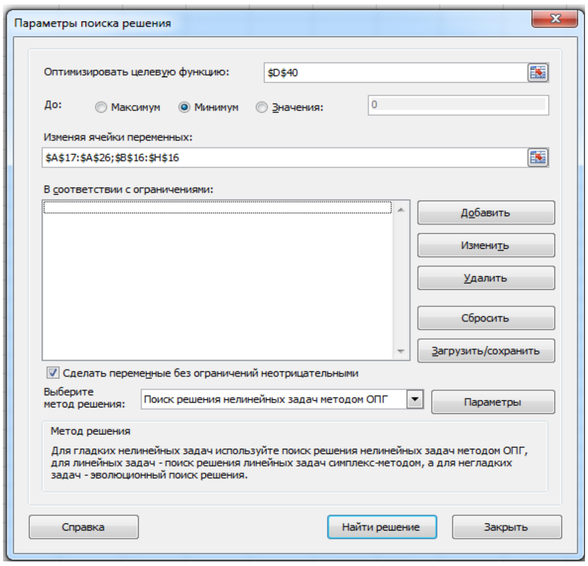

Figure 4. Solver customization parameters

We press the key Найти решение (Solve) and see the result shown in the figure 5. The estimates of the subjects' competitiveness are demonstrated in the cells A17-A26, and the estimates of the criteria feasibility are shown in the cells B16-H16.

14								
15		Матрица вероятностей (8)						
16	θ / β	1,517652	2,080859	4,077441	1,818875	1,632149	0	0,951604
17	2,061312	0,632664	0,495113	0,11752	0,560314	0,605674	0,887086	0,752075
18	2,337186	0,694138	0,563733	0,149281	0,626753	0,669304	0,91191	0,799886
19	1,40399	0,471615	0,336961	0,064558	0,397742	0,443206	0,802816	0,611206
20	1,613589	0,523966	0,385262	0,078431	0,448858	0,49536	0,833909	0,659706
21	2,348671	0,696571	0,566556	0,150745	0,629436	0,671841	0,912829	0,801718
22	10,40929	0,999862	0,999759	0,998224	0,999814	0,999846	0,99997	0,999922
23	1,580939	0,515816	0,377559	0,076104	0,440795	0,4872	0,829337	0,652338
24	3,266152	0,851764	0,765898	0,307616	0,809579	0,836717	0,963249	0,910075
25	2,037395	0,627088	0,489136	0,115062	0,554414	0,599947	0,884668	0,747588
26	1,719169	0,55021	0,41055	0,08641	0,475094	0,521741	0,848022	0,682994
27								
28		Слагаемые целевой функции (11)						
29		0,01408	0,007701	0,020546	0,01542	0,026434	0,008925	0,031771
30		2,75E-05	0,039075	0,069697	0,000429	0,154172	0,005432	6,5E-09
31		0,110478	0,013131	0,290028	0,023461	0,017209	0,027217	0,07558
32		0,113121	0,024026	0,006228	0,001432	0,061066	0,01931	0,001782
33		9,41E-06	0,000783	0,018179	0,00052	0,075382	0,462483	0,00483
34		0,19989	4,08E-08	2,52E-06	2,07E-08	0,111914	0,251975	0,079969
35		0,027139	0,124919	0,004633	0,000999	0,057739	0,020388	0,152539
36		0,001861	0,000814	0,050828	0,021756	0,018663	0,000945	5,08E-05
37		0,111251	0,05852	0,010591	0,014306	1,95E-09	0,009311	0,001374
38		0,162151	0,031032	0,005973	0,165316	0,0542	0,084783	0,050246
39								
40	Целевая функция (11):			3,626044				

Figure 5. The calculation results in MS Excel

We compare the results with the results obtained by the additive method (2), but using the formula taking the weights into consideration $X_n = \sum_{j=1}^{L} w_j u_{nj}$. For that purpose the both estimates we normalize into the scale, so that the sum of the estimates was 1. The results of the estimates are shown in the table 4 and figure 6–7 shows the same estimates without weights, for comparison. We can see, that the estimates correlate with each other quite well, but there are certain differences. For example, the biggest estimate obtained from the additive method belongs to the subject C8, while the one obtained from the Rasch's method it belongs to C6. This happened due to completely different approaches to the estimates calculations.

Table 4.

Normalized estimates of the subjects' competitiveness obtained from additive and Rasch's method for latent variable estimation

Subjects	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Additive	0.101	0.111	0.090	0.086	0.092	0.126	0.081	0.136	0.097	0.080
Rasch's	0.072	0.081	0.049	0.056	0.082	0.362	0.055	0.113	0.071	0.060

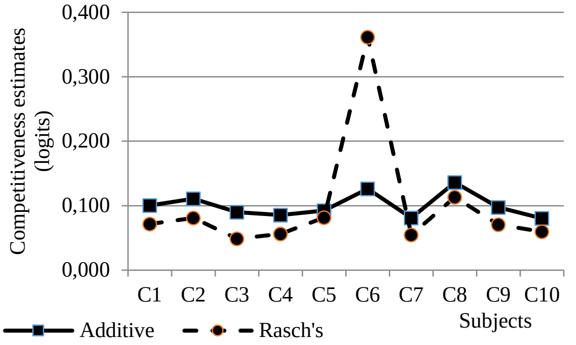

Figure 6. Normalized estimates of the subjects' competitiveness taking the criteria's weights based on additive and Rasch's methods for latent variables estimation

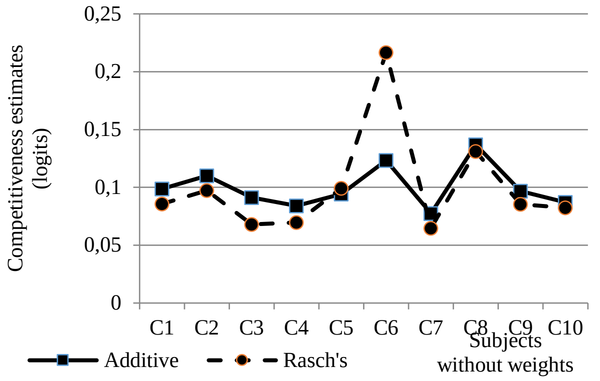

Figure 7. Normalized estimates of the subjects' competitiveness without weights based on additive and Rasch's methods for latent variables estimation

Table 5 demonstrates the criteria feasibility estimates. We can see, that the least feasible (problematic) criterion for this group of subjects is К3, and the most successful is criterion К6. We should note, that in accordance with (6) and (7), the higher is the criterion's estimate, the less feasible it is.

Table 5.

Criteria feasibility estimates (absolute and normalized to the sum of 1)

Criterion	К1	К2	К3	К4	К5	К6	К7
Absolute	1,518	2,081	4,077	1,819	1,632	0,000	0,952
Normal-ized	0,126	0,172	0,338	0,151	0,135	0,000	0,079

Conclusion

Let us stress out, that the suggested model allows introduction of any quantitative characteristic of competitiveness as the estimated variable after analyzing the factors affecting it. Such factors in their quantitative estimation become the models' criteria, and the estimation accuracy does not change anyway.

The variants for this model appliance are the following:

i) comparison of the applicants for the same vacancy;

ii) comparison of a company's, or department's employees;

iii) comparison of the individual within a group, for example, graduates of the same educational organization or the same educational programme;

iv) comparison of competitiveness of the same individual during the different periods of his/her work life, etc.

This fact considerably increases the area of the model's use which is not limited to the labour market competitiveness of individuals, but can be applied for companies' competitiveness within it.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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