THE MODELS FOR COMPANY'S HUMAN CAPITAL ESTIMATION, BASED ON THE STOCHASTIC FRONTIER APPROACH

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Abstract

This paper contributes to the development of the methodology of company's productive potential estimation by suggesting the approach to the estimation of its human capital, based on the stochastic frontier approach. The results of the empirical analysis of a scientific organization's human capital are presented, supporting the possibility of the application of the proposed approach to the estimation of the human capital amount and efficiency from both the company and its employees' perspectives.

Keywords*: intellectual capital, human capital, human capital determinants, human capital efficiency, econometric model, stochastic frontier approach.*

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1. Introduction

In spite of the successful examples of experimental approbation of the approach used to assess the production potential of the company (Kumbhakar et al. 1991; Aivazian, Afanasyev 2011), the issues related to its human capital evaluation remain unresolved. One of the first problems to mention is the description of the determinants of human capital and the formation of its integral estimates. This paper develops the approach suggested by the authors in (Aivazian, Afanasyev 2010). For an integrated assessment of human capital, we suggest the request approach based on the stochastic frontier approach. Efficiency of its application to modeling company production potential was shown in (Afanasyev 2006; Aivazian, Afanasyev, Makarov 2008; Aivazian, Afanasyev 2009; Aivazian, Afanasyev 2011; Pitt, Lee 1981; Reifschneider, Stevenson 1991; Taymaz, Saatçi 1997).

The idea of using the stochastic frontier approach in modeling the human capital with the introduction of the basic and special characteristic of its factors, and factors of efficiency of its use, is natural. General description of such a model is quite simple. The main difficulty when carrying out an empirical estimation of this model is its econometric implementation. The reason is that the choice of measurable determinants of the human capital of the company and of its employees, for the use efficiency of human capital, and model specification substantially depend on the production profile of the company. All of these questions need to be addressed separately for each narrow segment of the core business of companies. In this paper, we have selected research centers and scientific organizations as such segments.

In this paper the human capital (HC) is defined as the main component and the source of intellectual capital. Experts in the field of knowledge economy use the word "knowledge" as a synonym for the term "intellectual capital" (IC) – Makarov 2009; Makarov, Kleiner 2007.

We recall some basic assumptions adopted and used in this research. T. Schultz (the Nobel Prize laureate in 1979) notes that all human resources and abilities are either innate or acquired. Everyone is born with an individual set of genes, which determine his innate human potential. The acquired valuable qualities of a person that can be strengthened by relevant investments are referred to as human capital (Schultz 1960). T. Schultz was one of the first to introduce the concept of human capital as a production determinant, and the base and engine of an innovative economy. He proved that human capital had the necessary production features accumulation and reproduction.

G. Becker (the 1999 Nobel Prize laureate) argues that human capital is a set of experience, knowledge and skills of a person (Becker, 1964). As a human capital investment G. Becker considered mainly the cost of education and training. Becker specially contributed to the development of the theory of competition, strategy and development firm. He highlighted the particular importance of special education, expertise and skills. Special training of employees creates a competitive advantage resulting in firm-specific and significant features of its products. It is believed that the human capital management should be monitored alongside the following dimensions: education, professional qualifications, work-related knowledge and skills, professional capabilities.

The social capital (or social networks) plays a special role in the human capital of the company. This concept was introduced by P. Bourdieu (1986) in the article to denote the social networks, which can be the source of benefits accumulation. In the knowledge economy, social relations are not solely driven by income-level, but they also contribute to the creation and dissemination of new knowledge (Makarov 2008). Social capital is the basis for cooperation and coordination. Keeping this in mind, we use the following definition of the company employee's human capital. Human capital is a set of experience, knowledge, skills, and abilities and acquired social relations that are used to increase the level of professional activity and to gain competitive advantage.

Investments in human capital are essential features for the company. Investments in physical capital justify the cost savings. Since the company owns the physical capital, all other things being equal, the cost savings associated with its acquisition increase the competitiveness of the company. Human capital cannot be part of the company's property. The company only employs its services. Saving on payment of these services may be contrary to the goal of improving competitiveness, as it increases the risk of loss of human capital. During the crisis, the risk is relatively small due to the falling demand for labor. During the period of economic growth for the purpose of consolidation of human capital services and for the reduction of the risk of loss of the primary source of income, the company should establish salaries above its peers' levels. The growth of the company's competitiveness is a result of its efforts to develop the human capital of its employees and increase its efficiency.

In (Ordones de Pablos 2005) various factors of human capital are described and the general definition of the human capital of the company's management is provided. Structuring concepts of human capital contributes to the notion of "competence". Competence is a set of knowledge, skills, abilities and qualities of staff needed to carry out specific tasks (functions). Competence is the main component of the specific human capital, which has a special role in the formation of competitive advantages, as emphasized by G. Becker (1964). Given that an employee should undertake several key functions, we can say that he must have a certain set of competencies. Having information about the competencies, you can get an idea of human capital specific determinants.

2. Description of approaches to assessing human capital

Methods for measuring HC are closely related to the approaches used to measure intellectual capital. Basic principles of measurement of intellectual capital are presented by E. Sveybi on his personal website (Sveiby 2010). He identifies 42 methods of measuring intellectual capital that form the basis for the four approaches. The first approach uses the Direct Intellectual Capital (DIC) methods displaying cumulative score for the identified and evaluated monetary values of individual assets or components of intellectual capital. The second approach uses the Market Capitalization (MCM) methods. In this case, the calculated difference between the market capitalization of the company and its shareholders' equity, and the resulting value is considered as the value of its intellectual capital or intangible assets. The third approach is based on the Return on Assets (ROA) methods. The ratio of average income before taxes for a certain period to the physical assets of the company is compared with the corresponding statistics for the industry as a whole. To calculate the average additional income from the use of intellectual capital, the physical assets of the company are multiplied by the resulting difference. Next, the direct capitalization or discounted cash flow method can be applied to determine the total value of the intellectual resources of the company. And finally, the fourth approach is based on the Scorecard (SC) methods. This approach implies the identification of various components of intangible assets or intellectual capital and the construction of various indicators and indices on the basis of those components. In each of these approaches it is possible to distinguish specific methods for the valuation of the main component of the IC, i.e. human capital.

The approaches for assessing human capital proposed in this paper are a synthesis of ROA and SC ones based on the stochastic frontier approach. It is assumed that the company possesses a set of its employee's human capital (HC) determinants. We also assume that the values of variables that characterize these determinants can be measured for each employee. Then we distinguish two groups of human capital determinants measured for each employee: general (common) and specific determinants. It is assumed that HC common determinants are included as ordinary explanatory variables in the model specification. Specific determinants vary by the company, depending on what employees' competencies it supervises and develops. In addition to the HC determinants, HC use efficiency is considered. These factors can be divided into two groups: the company efficiency factors and the employee-efficiency factors.

HC is regarded as a determinant of the employee's performance and the amount of his salary. In accordance with (Aivazian, Afanasyev 2010), the maximum income that the employee can get given the HC is used efficiently is chosen as a measure of employee's HC. It is assumed that part of the salary is fully determined by the values of the general (common) HC determinants. Another part also depends on the results of the impact of specific and latent factors, including HC determinants, generating random effect on salary, as well as the characteristics of the HC efficiency factors.

We distinguish two components of the employee's total salary:

- The fixed part of salary. It is assumed that this part of the employee salary is determined by a set of common HC factors, defining her position in the organizational structure. For example, the fixed part of the scientist's salary is determined by his position and academic degree. The human capital efficiency does not directly affect the size of the fixed part of salary, but may be taken into account when deciding whether to promote or demote its staff.

- Complimentary (additional) part of the employee's salary received in addition to the fixed part. The size of the additional salary is determined by the characteristics of *all* HC determinants, namely, general, specific, efficiency as well as the impact of latent factors. Complimentary part of the salary may include the so-called incentive allowance, depending on the specific factors of HC. Incentive allowance may be regarded as a premium paid to the employee who develops his competences in the direction favored by a company.

The following approaches to the HC estimation can be used for academic and non-profit organizations, as well as for companies working in the field of non-physical production and services sectors. If the total salary consists only of a fixed part and a complimentary part of the salary is absent, the problem of HC estimation is trivial, and the use of this approach is inappropriate. In this case, the estimate of the employee's HC is the actual amount of his salary. That is why we assume that employees receive an additional pay.

We consider the general structure of models providing operational implementation of the above stated principles of the HC measurement and valuation. For this purpose, we introduce the following notations.

$y_j, y_j^{(0)}, y_j^{(1)}\ y_j^{(2)}$ are the total, fixed (base), complimentary and the part of the additional salary of j^th^ employee, which is defined as the stimulating premium, if there is any, respectively.

$q_j = (q_j^{(1)}, \dots, q_j^{(m)})$ are the values of common determinants of j^th^ employee HC,

$w_j = (w_j^{(1)}, \dots, w_j^{(n)})$ are the values of specific determinants of j^th^ employee HC.

In this paper we empirically implement two competitive approaches. The research is based on the data for one academic institution, for details see below.

Approach 1 It is assumed that the fixed (base) part of the salary is determined only by the values of common factors q (i.e. HC specific determinants have no impact on it), and the amount of complimentary salary $(y^{(1)})$ is modeled according to (Aivazian, Afanasyev 2010), using the stochastic frontier approach. Then

$$y_j = y^0(q_j) + y^1(q_j, w_j, \varepsilon_j) = y^0(q_j) + h(w_j; q_j \mid \Theta)\Psi(\varepsilon_j), \qquad (1)$$

where $h(w, q \mid \Theta)$ is a deterministic function of the specific $w = (w^{(1)}, \dots, w^{(n)})$ and common $q = (q^{(1)}, ..., q^{(m)})$ determinants depending on unknown (estimated on the available observations) parameters $\Theta = (\theta_1, \dots, \theta_k)$; $\Psi(\varepsilon)$ is appositive-valued monotonically increasing function of $\varepsilon = \nu - u$; ν is a $(0; \sigma_\nu^2)$- normally distributed random variable reflecting the random effects on $y^{(1)}$ unaccounted factors ($\nu \in N\,(0; \sigma_\nu^2)$), and *u* is a non-negative, independent of ν random variable, reflecting the effect of a decrease in the employee's complimentary salary resulting from its inefficient HC use . The refinement of the general form of the functions h and Ψ and stochastic nature of the random variable u will be provided below in the discussion of the model specification (1).

Approach 2 In this approach, the size of the fixed portion salary depends not only on the general, but also on the specific determinants of the HC. For example, an employee of an academic institution, who has a given position and possesses certain academic degree, must demonstrate a certain level of HC, characterized by specific determinants (parameters of the HC), in order to receive a fixed portion of her salary. It is necessary to provide evidence for the level of qualification. Therefore the amount of total salaries, including the fixed part, is determined by the values of general and specific factors of the HC. In this case the employee's total salary will be modeled by the following regression relationship

$$y_j = h(w_j; q_j \mid \Theta) \cdot \Psi(\varepsilon_j) . \quad (2)$$

The refinement of the general form of the functions h and Ψ, and stochastic nature of random variables ν и u from the difference $\varepsilon = \nu - u$ will be provided below.

The decision regarding the choice of one of these approaches by the company (academic institution), depends on the specific form of fixed salary. In this paper, both approaches as well as the results of the comparison will be presented.

3. Analyzed Models Specification

In our case, the problems of model specification include the establishment of the general form of the functions h and Ψ and the adoption of certain assumptions about the stochastic nature of ε, ν и u in proportions (1) and (2).

Having analyzed a very wide class of models (more than forty different options were assessed), we selected the following two versions of the general form of the function h.

Version 1:

$$h(w; q \mid \Theta) = \theta_0 (w^{(1)})^{\theta_1} \cdot \ldots \cdot (w^{(n)})^{\theta_n} \cdot \exp\left\{ \sum_{l=1}^{m} \theta_{n+l} \cdot q^{(l)} \right\}. \quad (3)$$

Version 2:

$$h(w; q \mid \Theta) = \theta_0 (w^{(1)})^{\theta_1} \cdot \ldots \cdot (w^{(n)})^{\theta_n} . \quad (4)$$

Then, in accordance with accepted approaches to the construction of models of stochastic frontier, the function $\Psi(\varepsilon)$ in the models (1) and (2) takes the form of

$$\Psi(\varepsilon) = \exp\{\varepsilon\}, \quad (5)$$

The random residual is represented as the difference

$$\varepsilon = \nu - u , \quad (6)$$

The values of the components ν и u have been described in the model representation (1). In line with the methodology of stochastic frontier approach, the random variable $TE_j = \exp\{-u_j\}$ characterizes the efficiency of the company employees' HC. Note that when evaluating the efficiency, technical difficulties may arise due to the method of the model construction, since the random variables u_j are non-observable (latent). However, the introduction of an adequate and suitable parameterization of the distribution of the random variables u_j enables to analyze the characteristics of the random variable TE_j. Then we consider two options of the parameterization of the random variable u_j (recall that in both cases, the variable u_j is regarded as statistically independent for ν_j non-negative random variable).

Option 1 If the factors of HC efficiency are not taken into account, it is usually considered (cf. Kumbhakar, Lovell 2004) that the random variable for the j[th] employee has an exponential distribution with the density function

$$f_j(u) = \frac{1}{\sigma_u^2}\exp\left(-\frac{u}{\sigma_u^2}\right), \tag{7}$$

where the parameter σ_u^2 does not depend on j.

Given the estimated residual values ε_j, the random variable TE_j is then estimated by the average value of the conditional distribution of the exponential component of the inefficiency (cf. Kumbhakar, Lovell 2004):

$$\mathrm{E}(\exp\{-u_j\} \mid \varepsilon_j) = \frac{1-\Phi(\sigma_v - \tilde{\mu}_j / \sigma_v)}{\Phi(\tilde{\mu}_j / \sigma_v)} \exp\left\{-\tilde{\mu}_j + \frac{1}{2}\sigma_v^2\right\}$$

where $\tilde{\mu}_j = -\frac{\sigma_v^2}{\sigma_u^2} - \varepsilon_j$,

$\Phi(.)$ — Standard normal distribution function.

Option 2 If it is necessary to take into account the factors of the HC efficiency, in accordance with (Battese, Coelli 1988), we consider u_j as a non-negative random variable having a normal distribution truncated at zero, with a mean δz_j and variance σ_u^2 and characterizing the effects of all HC efficiency determinants on the employee's salary:

$$u_j \in N^+(\delta z_j; \sigma_u^2), \tag{8}$$

where δz_j is the inefficiency function, which characterizes the impact of efficiency factors $z_j = (1, z_j^{(1)}, \ldots, z_j^{(p)})^{\mathrm{T}}$, a $\delta = (\delta_0, \delta_1, \ldots, \delta_s, \ldots, \delta_p)$ is the vector of coefficients of inefficiency function (estimated from the available observations).

Then, in accordance with (Kumbhakar, Lovell 2004):

$$\mathrm{E}(\exp\{-u_j\} \mid \varepsilon_j) = \frac{1-\Phi(\sigma_* - \tilde{\mu}_j / \sigma_*)}{\Phi(\tilde{\mu}_j / \sigma_*)} \exp\left\{-\tilde{\mu}_j + \frac{1}{2}\sigma_*^2\right\},$$

where $\tilde{\mu}_j = (\delta z_j \sigma_v^2 - \varepsilon_j \sigma_u^2) / \sigma^2$, $\sigma_*^2 = \sigma_u^2 \sigma_v^2 / \sigma^2$, $\sigma^2 = \sigma_u^2 + \sigma_v^2$.

Note that (1) and (2) under the assumptions (3) - (8) generalize the well-known econometric model of Mincer (1975) that also uses the value of an individual's income as a dependent variable. Mincer's model, as model (1) and (2), suggests the possibility of forming a set of components of human capital to obtain estimates of their values for each employee when level of education, training, psychometric characteristics, and health are measured and accounted for. However, the valuation of human capital, obtained by the Mincer's model is correct only under the assumption that human capital is used efficiently. An important feature of the models (1) and (2) is that they allow you to evaluate and take into account the efficient use of the employee's human capital. Both the efficient use by the employee and the company are controlled for.

The indicator which we use as a basis for assessing the employee's HC is calculated as the value of its potential income y_j^{pot}, i.e. the expected value of the actual income y_j in the case of the efficient use of HC.

In case (1) we have

$$y_j^{pot} = y_j^{(0)} + h(q_j, w_j, \gamma)\,\mathrm{E}(\exp\{v_j\} \mid \varepsilon_j) = y_j^{(0)} + y_j^{(1)} / TE_j \,. \tag{9}$$

In case (2)

$$y_j^{pot} = h(q_j, w_j, \gamma)\,\mathrm{E}(\exp\{v_j\} \mid \varepsilon_j) = y_j / TE_j \,. \tag{10}$$

Given the estimated value ε_j, the value $\mathrm{E}(\exp\{-u_j\} \mid \varepsilon_j)$ is a measure of a salary decrease due to the inefficient use of human capital. The value

$\mathrm{E}(\exp\{v_j\} / \varepsilon_j) = \exp\{\varepsilon_j\}\,\mathrm{E}(\exp\{u_j\} / \varepsilon_j\}$ is an adjustment factor applied to the salary determined by the basic factors of human capital to control for the impact of latent HC factors determinants.

To estimate HC_j of employee's HC we consider the ratio y_j^{pot} of his income (expected in case of the efficient use of HC) to the value $y^{\min}$ (i.e. the salary of an employee with a minimum duration of education and no work experience, who can be hired by the institution). For example, in an academic institution $y^{\min}$ is the salary of a laboratory assistant. Then:

$$HC_j = \frac{y_j^{pot}}{y^{\min}} \,. \tag{11}$$

Employee HC can be estimated in monetary terms as the difference in values y_j^{pot} and $y^{\min}$. Therefore, in addition to evaluating HC_j we should consider the measure $\widetilde{HC}_j = y_j^{pot} - y^{\min}$. The estimate (11) is more convenient because it allows to comparing the HC of employees for institutions, which differ in wage levels.

The estimate (11) of the employee's HC develops the approach used in (Mulligan, Sala-i-Martin 1995). K. Milligan and C. Sala used the ratio of the employee's total income to the payroll of a person with zero years of education and no work experience as a measure of human capital.

If the value $y^{\min}$ is the same for all analyzed companies, we can estimate the HC by the following:

$$HC = \sum_j^N HC_j = \frac{\sum_j^N y_j^{pot}}{y^{\min}} \quad \text{and} \quad \widetilde{HC} = \sum_j^N \widetilde{HC}_j = \sum_j^N y_j^{pot} - N * y^{\min} \,,$$

HC of the institution equals to the sum of estimates of all employees' HC, as well as their average values $HC_{cp} = HC / N$ and $\widetilde{HC}_{cp} = \widetilde{HC} / N$. We believe that the human capital belongs to the company's employees. The company employs only the services of human capital, but is not its owner. At the same time, the company can create a synergy effect when of their employees' human capital interacts.

The efficiency of the company's HC is determined by the ratio of the actual total return of employees to the value of their total income expected under the efficient use of HC assumption:

$$TE_c = \frac{\sum_j^N y_j}{\sum_j^N y_j^{pot}}.$$

Additional issues of this approach are discussed in econometric modeling section when a particular example of an academic institution is considered.

4. Data description

The general (common) determinants are described by the two qualitative (categorical) variables:

$q^{(1)}$ is the employee position out of six grades (junior research assistant, research assistant, senior research assistant, leading research assistant, chief research assistant, head of the laboratory).

$q^{(2)}$ is the academic degree obtained (none, candidate of science, doctor of science).

Accordingly, the variable $q^{(1)}$ produces five dummy variables $d_j^{(1)}$ ~ $d_j^{(5)}$, with the following values[1]:

$d_j^{(1)} = 1$, if j th employee occupies the position «*head of the laboratory*» (otherwise $d_j^{(1)} = 0$);

$d_j^{(2)} = 1$, if j th employee occupies the position «*chief research assistant*» (otherwise $d_j^{(2)} = 0$);

$d_j^{(3)} = 1$, if j th employee occupies the position «*leading research assistant*» (otherwise $d_j^{(3)} = 0$);

$d_j^{(4)} = 1$, if j th employee occupies the position «*senior research assistant*» (otherwise $d_j^{(4)} = 0$);

$d_j^{(5)} = 1$, if j th employee occupies the position «*research assistant*» (otherwise $d_j^{(5)} = 0$).

Similarly, the variable $q^{(2)}$ generates two dummy variables $s_j^{(1)}$ and $s_j^{(2)}$, with the following values :

$s_j^{(1)} = 1$, if j th employee has a degree «candidate of science» ($s_j^{(1)} = 0$ otherwise);

$s_j^{(2)} = 1$, if j th employee has a degree «doctor of science» ($s_j^{(2)} = 0$ otherwise).

The values of variables $d_j^{(l)}$ и $s_j^{(m)}$ are recorded as at the end of 2010.

Specific determinants include four quantitative variables:

$w_j^{(1)}$ is the volume of the latest[2] monographs, textbooks, teaching manuals published by a j employee over a given period;

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[1] In the extended version of the sample, there were six dummies $d_j^{(0)} = 1,$ if *j* employee occupies a senior management position ($d_j^{(0)} = 0,$ otherwise).

$w_j^{(2)}$ is the number of published articles in refereed journals (same period is considered);

$w_j^{(3)}$ is the number of conferences presentations (same period is considered);

$w_j^{(4)}$ is the number of types of scientific and organizational work in which the employee takes part on a regular basis (same period is considered).

Besides the above measures of specific determinants expressed in natural units we have at our disposal the relative measures of the same variables based on the conditional scoring (scoring rules are defined in internal procedures of the academic institution, see (Ushkova 2011). We will denote the corresponding measures by variables $\tilde{w}_j^{(l)}$ $(l = 1, 2, 3, 4)$.

From the survey results we obtained the characteristics $z_j^{(1)}$ and $z_j^{(2)}$ with efficiency factors of HC for 47 employees. The aggregate score $z_j^{(1)}$ reflects the employees' perception of deficiencies in working conditions. The aggregate score $z_j^{(2)}$ reflects the level of employees' motivation.

The analyzed dependent (explained) variables $y_j, y_j^{(0)}, y_j^{(1)}$ и $y_j^{(2)}$ were recorded in thousands of rubles and averaged over a three year period of 2008 ~ 2011.

Thus, we had the following initial data

Array 1: $\left\{d_j^{(1)}, d_j^{(2)}, d_j^{(3)}, d_j^{(4)}, d_j^{(5)}; s_j^{(1)}, s_j^{(2)}; w_j^{(1)}, w_j^{(2)}, w_j^{(3)}, w_j^{(4)}; y_j, y_j^{(0)}, y_j^{(1)}, y_j^{(2)}\right\}$,

$j = 1, 2, \ldots, 172.$

Array 2: contains array 1 data with the replacement of "natural" rates by their "scores" equivalents $\tilde{w}_j^{(l)}$ $(l = 1, \ldots, 4)$.

Array 3: contains array 1 data with additional data on five senior management members $\left\{d_j^{(0)}, d_j^{(1)}, d_j^{(2)} d_j^{(3)}, d_j^{(4)}, d_j^{(5)}; s_j^{(1)}, s_j^{(2)}; w_j^{(1)}, w_j^{(2)}, w_j^{(3)}, w_j^{(4)}; y_j, y_j^{(0)}, y_j^{(1)}, y_j^{(2)}\right\}$, $j = 1, 2, \ldots, 177.$

Array 4: contains array 3 data with the replacement of "natural" indicators $w_j^{(l)}$ by their "scores" equivalents $\tilde{w}_j^{(l)}$.

Array 5: contains data $\left\{ s_j^{(1)}, s_j^{(2)}; w_j^{(1)}, \ldots, w_j^{(4)}; z_j^{(1)}, z_j^{(2)}; y_j^{(1)} \right\}$ only for the 47 employees who gave information about the efficiency factors $z_j^{(i)}$.

Array 6: contains array 3 data with the replacement of "natural" indicators $w_j^{(l)}$ by their "scores" equivalents $\tilde{w}_j^{(l)}$.

[2] According to internal procedures of the academic institution considered the publication track record included 2008-2010 years.

5. Models and the Econometric Analysis Output

The following models are designed to assess the human capital of employees and of an academic institution as a whole as well as to measure the efficiency of HC use by an employee and a company thus providing some additional implications for management.

The differences among the models are due to the following factors:

[1] the choice of the dependent (explained) variable;

[2] a set of explanatory variables;

[3] the general form of the function h;

[4] the presence (absence) of residuals and the type of distribution function;

[5] units of measurement for specific determinants in w;

[6] the composition of the initial data.

Accordingly, we will further evaluate and analyze the models M 1 ~ M 13, with characteristics presented in Table 1.

Table 1: Characteristics of the analyzed models

Model	Dependent (explained) variable	Explanatory variables	Function h	Law of residuals distribution u_j	Units of measurement for determinants w	Data array
M 1	$y^{(1)}$	$w;q$	(3)	(7)	natural	1
M 2	$y^{(1)}$	w	(4)	(7)	natural	1
M 3	$y^{(1)}$	$\tilde{w};q$	(3)	(7)	scores	2
M 4	$y^{(1)}$	$\tilde{w}$	(4)	(7)	scores	2
M 5	y	$w;q$	(3)	(7)	natural	1
M 6	y	$\tilde{w};q$	(3)	(7)	scores	2
M 7	$y^{(1)}$	$w;q$	(3)	(7)	natural	3
M 8	$y^{(1)}$	w	(4)	(8)	natural	5
M 9	$y^{(1)}$	$\tilde{w}$	(4)	(8)	scores	6
M 10	$y^{(2)}$	$\tilde{w}$	(4)	not involved	scores	4
M 11	$y^{(2)}$	w	(4)	not involved	natural	2
M 12	$y^{(1)}$	$w;q$	(3)	not involved	natural	1
M 13	y	$w;q$	(3)	not involved	natural	1

For the purpose of a preliminary analysis we use the following M 12 econometric model specification:

$$\ln y_j^{(1)} = \theta_0 + \sum_{l=1}^{4} \theta_l \cdot \ln w_j^{(l)} + \sum_{l=1}^{5} \theta_{4+l} \cdot d_j^{(l)} + \theta_{10} \cdot s_j^{(1)} + \theta_{11} \cdot s_j^{(2)} + \nu_j, \quad (12)$$

Which does not include the residual random variable u_j when determining the efficiency of human capital. It is shown that the presence (absence) of academic degrees does not have a significant impact on the value of complimentary salary. A common sense explanation of this fact is a high correlation of the variables $s^{(1)}$ и $s^{(2)}$ with variable $d^{(1)} \sim d^{(5)}$, i.e. the multicollinearity phenomenon. This fact is observed in other model specification, so the variables $s^{(1)}$ и $s^{(2)}$ were excluded from further estimations.

Let us analyze the M 1 model:

$$\ln y_j^{(1)} = \theta_0 + \theta_1 \ln w_j^{(1)} + \ldots + \theta_4 \ln w_j^{(4)} + \theta_5 d_j^{(1)} + \ldots + \theta_9 d_j^{(5)} + v_j - u_j, \quad (13)$$

where u_j has an exponential distribution. It turns out that the scientist's position has a significant influence on the amount of additional income, and all the coefficients have the expected sign, the characteristics of the 3rd (presentations at conferences) and 4th (scientific and organizational work) human capital specific determinants are significant, the inefficiency is also significant. The estimates HC_j of HC for all employees and $TE = E(\exp\{-u_j\} \mid \varepsilon_j)$ of HC efficiency are obtained. Given these values we have estimated the amount and the efficiency of the organization's HC (see Table 2). Table 1.1 in Appendix 1 shows the HC efficiency estimates for 10% of employees with the highest and 10% with the lowest values, and HC_j estimates for these employees.

For comparison purposes, Table 2 shows the valuation of HC derived from the M 2 model, which takes into account only the HC specific determinants:

$$\ln y_j^{(1)} = \theta_0 + \theta_1 \ln w_j^{(1)} + \ldots + \theta_4 \ln w_j^{(4)} + v_j - u_j, \quad (14)$$

where u_j has an exponential distribution.

The estimates of HC, obtained from the M 1 and M 2 models, without controlling for the common factors, are essentially identical. However, the employees' HC efficiency estimates differ significantly. Table 1.1 in Appendix 1 shows the lists of 10% of employees with the highest and 10% with the lowest estimates of the *HC efficiency* obtained from the M 1 and M 2 models. Table 1.2 in Appendix 1 shows the lists of 10% of employees with the highest and 10% with the lowest estimates of *human capital* HC_j, obtained from these models. Position (experience) is one of the characteristics of HC and has a significant influence on the additional income. The M 1 model, accounting for the experience of the staff to explain the value of the additional income is more adequate for the objectives of our research.

Similarly to the M 1 model we construct the M 3 model that accounts for the score-valued specific HC determinants.

$$\ln y_j^{(1)} = \theta_0 + \theta_1 \ln \tilde{w}_j^{(1)} + \ldots + \theta_4 \ln \tilde{w}_j^{(4)} + \theta_5 d_j^{(1)} + \ldots + \theta_9 d_j^{(5)} + v_j - u_j, \quad (15)$$

Accordingly, in parallel to M2 model we construct the M 4 model

$$\ln y_j^{(1)} = \theta_0 + \theta_1 \ln \tilde{w}_j^{(1)} + \ldots + \theta_4 \ln \tilde{w}_j^{(4)} + v_j - u_j, \quad (16)$$

By comparing the results presented in Table 2, we can conclude that the estimates of the institution's HC and its efficiency, obtained from the M 1 and M 2 models (using explanatory variables in natural units) and those obtained from the M 3 and M 4 models (where explanatory variables are measured in scores) are mostly the same. Therefore, to evaluate HC, one can use any form of explanatory variables that is more convenient for the institution and that is supported by the HC monitoring system.

Then we consider a model with the total salary as the dependent variable i.e. the model generated by (2) in specifications (3) and (4) of the function $h(w,q\,|\,\Theta)$. These models allow us to obtain estimates $HC, HC_{cp}, \widetilde{H}C, \widetilde{H}C_{cp}$ and TE_{cp} for human capital on the basis of expression (10).

For the purpose of a preliminary analysis we construct a M 13 type model

$$\ln y_j = \theta_0 + \theta_1 \ln w_j^{(1)} + \ldots + \theta_4 \ln w_j^{(4)} + \theta_5 d_j^{(1)} + \ldots + \theta_9 d_j^{(5)} + \theta_{10} s_j^{(1)} + \theta_{11} s_j^{(2)} + v_j \qquad (17)$$

The academic position and the two specific determinants (the 3rd and 4th) have a significant impact on the value of total income while the academic degree does not have a significant effect.

Let us analyze the M 5 model

$$\ln y_j = \theta_0 + \theta_1 \ln w_j^{(1)} + \ldots + \theta_4 \ln w_j^{(4)} + \theta_5 d_j^{(1)} + \ldots + \theta_9 d_j^{(5)} + v_j - u_j\,, \qquad (18)$$

where u_j has an exponential distribution. The analysis shows that the position has a significant effect on the amount of additional income, all the coefficients have the expected sign, specific HC determinants, except for the 1st one, are significant at the 10% significance level, the inefficiency factor is significant. The organization HC estimates (see Table 2) obtained from the M 5 model, in which the dependent variable is the total income, are higher than the estimates obtained from the M 1-M 4 models, based on additional income. Accordingly, the HC efficiency, estimated on the basis of the M 5 model is presented below. Let us compare the lists of 10% employees with the highest and 10% with the lowest estimates of the HC efficiency obtained from the M 1 and M 5 models (see Table 1.3 in Appendix 1). It follows that the M 5 model (using total income as the dependent variable) the HC efficiency is higher for employees in a higher-level positions.

By analogy with the M 3 model we construct the M 6 model

$$\ln y_j = \theta_0 + \theta_1 \ln \tilde{w}_j^{(1)} + \ldots + \theta_4 \ln \tilde{w}_j^{(4)} + \theta_5 d_j^{(1)} + \ldots + \theta_9 d_j^{(5)} + v_j - u_j\,, \qquad (19)$$

When comparing the lists of 10% employees with the highest and 10% with the lowest estimates of the HC efficiency obtained from the M 5 and M 6 models (see Table 1.3 in Appendix 1), a significant proximity of both efficiency and staff HC estimates is observed.

On the basis of the HC estimates from the M 1-M 6 models presented in Table 2 we conclude:

[7] M 1 – M 4 models using complimentary income as a dependent variable deliver the similar estimates of the institution's HC;

[8] Similarly, M 5-M 6 models' output does not differ though total income was used as a dependent variable;

[9] M 1 - M 4 models lead to results that are different from those obtained in M 5-M 6 models.

Table 2: Estimates of organization's HC from the M 1-M 6 models

Mo-del	income explained	Posi-tion	Units of measurement of the spcial factors	HC	HC_{av}	$\widetilde{HC}$ (thou-sands of rubles)	$\widetilde{HC}_{cp}$ (thou-sands of rubles)	TE_c
M 1	additional	yes	natural	889.3	5.17	65274	379.5	0,801
M 2	additional	no	natural	899.9	5.23	66238	385.1	0,791
M 3	additional	yes	scores	901.2	5.24	66357	385.7	0,790
M 4	additional	no	scores	891.1	5.18	65347	379.9	0,800
M 5	total	yes	natural	942.3	5.47	70101	407.5	0,748
M 6	total	yes	scores	947.7	5.51	70594	410.4	0,751

If the remuneration and incentives system adopted by a company is based on HC determinants, then the variance of the random variable $v_j - u_j$ in the M 1-M 6 models should be small. In other words, the amount of the employee's income will be determined to a large extent by a set of HC common and specific factors. In this case the value $\sum_{j=1}^{N} y_j^{pot}$ will be close to the size of the payroll. Consequently, when the remuneration and incentives system is based on the human capital determinants, the estimate of the company's HC may be based on the size of the payroll.

The M 1 - M 6 models described above are based on the data for 172 researchers. They do not include senior managers. In order to assess their human capital we need special factors accounting for the administrative work carried out by these staff members on a regular basis. The position only partially takes into account this fact. The M 7 model presented below was built for 177 employees and included the data on the five senior staff members. It allows us to trace how their inclusion in the sample alters the HC estimates for other researchers.

Model M 7:

$$\ln y_j^{(1)} = \theta_0 + \theta_1 \ln w_j^{(1)} + \ldots + \theta_4 \ln w_j^{(4)} + \theta_5 d_j^{(0)} + \theta_6 d_j^{(1)} + \ldots + \theta_{10} d_j^{(5)} + v_j - u_j, \qquad (20)$$

where $d_j^{(0)} = 1$, if the employee j is a member of the senior management team, otherwise $d_j^{(0)} = 0$; u_j has an exponential distribution.

The M 7 model is different from the model M 1 in that it takes into account the members of the senior management team. As a result, the number of employees in the sample increased from 172 to 177. The estimates of the organization's HC and the efficiency of its use for the sample of 177 employees are provided in table 3.

Table 3: Estimates of organization's HC by the M 7 model

HC	HC_{cp}	$\widetilde{HC}$ (Thousands of rubles.)	$\widetilde{HC}_{cp}$ (Thousands of rubles.)	
1013.8	5.70	76057	427.3	TE_c 0,798

The inclusion of 5 employees in managerial positions in the sample implied increase of HC and $\widetilde{HC}$ estimates. The average values have also risen, since the senior managers included in the sample have higher values of human capital factors. Of particular interest are the HC estimates of the 172 employees without senior managers obtained from the M 7 model. The following table summarizes these estimates and compares with those obtained from the M 1 model.

Table 4. Estimates of organization's HC by M 7 and M 1 models

Model	HC	HC_{cp}	$\widetilde{HC}$ (Thousands of rubles.)	$\widetilde{HC}_{cp}$ (Thousands of rubles.)	TE_c
M 7 (172)	897.9	5.22	65624	381.5	0,799
M 1	889.3	5.17	65274	379.5	0,801

All estimates of HC in the M 7 model, obtained for a sample of 172 employees are higher than for the M 1 model. As can be seen from the results for 10% of employees with the highest and the lowest 10% of the estimates presented in Table 1.4 in Appendix 1, the estimates of the employees' HC in the M7 model increased compared with the estimates from the M1 model. This effect is the result of inclusion of the employees with high performance factors of the HC in the M 7 model. The estimates of HC for 10% of employees with the highest and 10% with the lowest estimates of 177 employees, including members of management, and appropriate evaluation of the efficiency are also given in Table 1.4 in Appendix 1.

The characteristics $z_j^{(1)}$ and $z_j^{(2)}$ of efficiency factors for 47 employees were obtained from the survey. The aggregate score $z_j^{(1)}$ was obtained by processing the responses to the multiple-choice question "Do you see any flaws in your work?" The higher the score, the more persistent the efficiency issues are, in the employee's opinion. The aggregate score $z_j^{(2)}$ was obtained by processing the responses to the question "Are there circumstances that reduce your motivation for scientific work?" As stated above, the efficiency factors were not obtained for all, but only for 47 employees. So it was not possible to use them as inputs in the above models to assess the HC. However, the two models are built specifically to assess the significance of the efficiency factors of the HC:

Model M 8 $$\ln y_j^{(1)} = \theta_0 + \theta_1 \ln w_j^{(1)} + \ldots + \theta_4 \ln w_j^{(4)} + v_j - u_j, \quad (21)$$

Model M 9 $$\ln y_j^{(1)} = \theta_0 + \theta_1 \ln \tilde{w}_j^{(1)} + \ldots + \theta_4 \ln \tilde{w}_j^{(4)} + v_j - u_j, \quad (22)$$

where $u_j = N^+(\delta z_j, \sigma_u^2)$ is a truncated at zero normal distribution with mean

$\delta z_j = \delta_0 + \delta_1 z_j^{(1)} + \delta_2 z_j^{(2)}$, depending on the values of two efficiency factors with the estimates $z_j^{(1)}$ and $z_j^{(2)}$.

Both models capture the significant impact of the first determinant. Moreover, the estimate of the coefficient δ_1 is negative. The more problems the company faces, the more efficient the work is. Apparently, employees who work more efficiently are paying more attention to the problems that make their work more difficult. The estimates of the second determinant in the models are not significant. The views of staff about the presence of factors reducing the motivation have no significant impact on their work efficiency. We checked the adequacy of aggregation procedure that was used for determining the values of specific determinants.

Model M 10

$$y_j^{(2)} = \hat{\theta}_0 + \hat{\theta}_1 \tilde{w}_j^{(1)} + \hat{\theta}_2 \tilde{w}_j^{(2)} + \hat{\theta}_3 \tilde{w}_j^{(3)} + \hat{\theta}_4 \tilde{w}_j^{(4)} + v_j. \quad (23)$$

We evaluated the dependence of the average incentive bonuses on wages $y^{(2)}$ for 2008-2010 given the values of score-valued specific determinants for all 177 employees. The resulting R^2 = 0.7385 that is high enough, given that the premium amounts are calculated each year, and the regression was constructed for the mean values. All specific HC determinants are significant at 5% level. The one-notch contribution of $\hat{\Theta}_k$, calculated for each specific determinant, is approximately the same. The results indicate the adequacy of the aggregation procedure used in the calculation of the characteristics of the special HC factors in scores.

The same conclusion was reached when testing with the M 11 model using natural units-values determinants:

$$y_j^{(2)} = \theta_0 + \theta_1 w_j^{(1)} + \ldots + \theta_4 w_j^{(4)} + v_j \quad (24)$$

Note that the approach to the valuation of the institution's HC as the sum of its employees' HC estimates, based on a stochastic frontier approach, allows us to take into account the synergy effect achieved by combining the human capital of employees.

6. Conclusions

A model based on the use of the potential income value, calculated for the employee on the basis of the stochastic frontier approach allows us to obtain estimates of the human capital of the company. It can be interpreted in the context of efficiency and management capabilities of HC. The resulting estimates can form the basis for the decisions on HR management to develop human capital and efficiency of its use. To evaluate the activities aimed at improving the efficiency of human capital the concept of the achievable potential may be used (see Aivazian, Afanasyev 2009), which is based on the ability to control for the efficiency factors.

It was shown that in the HC employees' models the academic degree has no significant effect on the total and complimentary income. The estimates of employees' HC and of the institution's HC, obtained from the M 1 and M 2 models, are similar. Nevertheless, the estimates of the employees' HC efficiency are different. The M 1 model accounting for the experience of the staff to explain the value of the complimentary income is more adequate with respect to the objectives of the study. For the same reason, the M 3 model is preferred to the M 4 model.

The estimates of the organization's HC and its efficiency obtained from the M 1 model using natural units-valued determinants are close to the estimates by the M 3 model that is based on score-valued determinants. The same conclusion holds for the M 5 and M 6 models .Therefore, to evaluate the HC, we can use the determinants in any form that is more convenient for the institution and is supported by the HC monitoring system. If the determinants are measured in natural units one should focus on the use of the M 1 and M 5 models. If the determinants are measured in scores, one should focus on the use of the M 3 and M 6 models.

The estimates of the organization's HC obtained from the M 1 and M 3 models, where the dependent variable is the employee's complimentary income, do not differ. The estimates of the organization's HC obtained from the M 5 and M 6 models do not differ either.

If the remuneration and incentives system used by the organization is based on HC determinants, the assessment of human capital can be obtained based on the size of the payroll. Otherwise, the difference between the valuation of human capital and payroll can be material.

The comparative analysis of the M 1 and M 7 models shows that the inclusion of additional employees in the sample can lead to a change in estimates of other employees HC. Thus, the inclusion in the sample of employees with high values of HC factors leads to an increase in the HC estimates of other employees, which indicates the possibility of accounting for the synergy effect which arises when combining employees' HC within one institution.

Appendix 1

Table 1.1

M2 model : the employees' HC *efficiency* estimates (10% with the highest and 10% with the lowest values)				M1 model: the employees' HC *efficiency* estimates (10% with the highest and 10% with the lowest values)		
Employee	TE	HC		Employee	TE	HC
6	0.87	19.49		6	0.88	19.19
142	0.85	7.09		142	0.86	7.04
134	0.85	7.94		134	0.84	7.97
115	0.84	6.51		98	0.84	6.42
129	0.83	9.89		137	0.84	2.22
98	0.82	6.52		78	0.83	5.07
136	0.81	7.49		138	0.83	18.36
139	0.81	14.71		2	0.83	5.51
81	0.81	5.55		139	0.83	14.51
67	0.80	16.83		129	0.82	9.97
138	0.80	18.92		136	0.82	7.47
78	0.80	5.20		102	0.81	12.92
100	0.80	5.53		52	0.81	4.42
32	0.80	6.98		115	0.81	6.70
86	0.79	5.16		140	0.80	6.40
77	0.79	14.92		67	0.80	16.90
2	0.78	5.73		81	0.80	5.58
-				-		
150	0.31	1.04		76	0.31	3.74
170	0.31	2.01		171	0.31	5.34

48	0.26	2.22		150	0.29	1.09
13	0.25	5.91		33	0.28	3.06
76	0.24	4.15		163	0.28	2.39
110	0.23	2.24		13	0.27	5.65
37	0.22	3.32		170	0.24	2.26
51	0.18	1.42		37	0.22	3.29
163	0.17	2.94		119	0.21	1.67
126	0.17	2.39		126	0.21	2.23
60	0.16	2.58		110	0.20	2.42
109	0.15	2.21		51	0.15	1.64
119	0.15	1.90		88	0.12	2.34
88	0.14	2.18		60	0.12	3.02
155	0.07	1.44		155	0.06	1.68
105	0.01	1.44		105	0.02	0.93
106	0.01	1.42		106	0.01	1.44

Table 1.2

M 2 model : the employees' HC estimates (10% with the highest and 10% with the lowest values)				M 1 model : the employees HC estimates (10% with the highest and 10% with the lowest values)		
Employee	TE	HC		Employee	TE	HC
6	0.87	19.49		6	0.88	19.19
138	0.8	18.92		138	0.83	18.36
67	0.8	16.83		67	0.8	16.9
77	0.79	14.92		77	0.78	14.98
139	0.81	14.71		139	0.83	14.51
102	0.78	13.32		102	0.81	12.92
125	0.75	12.74		125	0.75	12.83
148	0.73	11.52		148	0.78	10.87
92	0.74	10.22		92	0.72	10.43
20	0.72	10.12		20	0.7	10.31
165	0.74	9.97		165	0.72	10.19
161	0.69	9.94		161	0.68	10.06
129	0.83	9.89		129	0.82	9.97
40	0.72	9.55		41	0.72	9.9
41	0.76	9.47		40	0.7	9.72
144	0.72	9.09		66	0.67	9.28
66	0.71	8.96		53	0.67	9.2
-	-			-	-	
110	0.23	2.24		137	0.84	2.22
48	0.26	2.22		117	0.53	2.16
109	0.15	2.21		59	0.43	2.02
23	0.41	2.2		75	0.56	1.96
88	0.14	2.18		123	0.53	1.94
75	0.43	2.14		50	0.62	1.78
123	0.4	2.12		155	0.06	1.68

170	0.31	2.01		119	0.21	1.67
119	0.15	1.9		51	0.15	1.64
49	0.34	1.87		48	0.55	1.55
155	0.07	1.44		109	0.37	1.5
105	0.01	1.44		106	0.01	1.44
51	0.18	1.42		49	0.63	1.34
106	0.01	1.42		150	0.29	1.09
158	0.35	1.26		158	0.48	1.06
17	0.47	1.21		105	0.02	0.93
150	0.31	1.04		17	0.7	0.89

Table 1.3

M 5 model : the employees HC efficiency estimates (10% with the highest and 10% with the lowest values)				M 6 model : the employees HC efficiency estimates (10% with the highest and 10% with the lowest values)		
Employee	TE	HC		Employee	TE	HC
6	0.94	18.28		6	0.93	18.38
142	0.91	6.87		142	0.90	6.92
134	0.90	7.76		134	0.90	7.80
78	0.90	4.97		78	0.90	5.00
138	0.90	17.33		138	0.90	17.43
2	0.90	6.13		2	0.89	6.16
139	0.90	13.82		139	0.89	13.90
136	0.89	5.36		136	0.89	5.39
98	0.89	15.65		98	0.89	15.74
67	0.89	6.36		67	0.89	6.40
129	0.89	7.16		129	0.89	7.20
81	0.88	4.59		81	0.89	4.61
32	0.87	9.68		32	0.88	9.73
102	0.87	5.49		102	0.87	5.52
52	0.87	6.70		52	0.87	6.74
77	0.87	12.41		77	0.87	12.49
100	0.87	13.96		100	0.87	14.04
-	-	-		-	-	-
49	0.46	3.51		49	0.46	3.53
147	0.45	2.40		147	0.45	2.42
170	0.43	3.50		170	0.43	3.52
22	0.41	3.32		22	0.43	3.33
145	0.40	3.33		145	0.40	3.35
158	0.40	1.98		158	0.39	1.99
110	0.39	3.27		110	0.39	3.28
88	0.39	5.02		88	0.38	5.05
65	0.35	4.60		65	0.34	4.63
60	0.34	6.14		60	0.33	6.17
17	0.33	2.16		17	0.31	2.17
171	0.27	8.03		171	0.27	8.08
155	0.22	3.01		155	0.21	3.02

150	0.17	2.86		150	0.17	2.88
51	0.10	3.76		51	0.10	3.78
105	0.05	2.46		105	0.06	2.47
106	0.04	3.47		106	0.05	3.49

Table 1.4

M 7 model : the employees HC estimates (10% with the highest and 10% with the lowest values of 172 employees, without five senior members)				M 7 model : the employees HC estimates (10% with the highest and 10% with the lowest values of 177 employees, with five senior members)		
Employee	TE	HC		Employee	TE	HC
6	0.82	20.41		174	0.80	23.97
138	0.77	19.59		173	0.80	22.77
67	0.79	17.14		6	0.82	20.41
77	0.76	15.27		138	0.77	19.59
139	0.78	15.13		67	0.79	17.14
102	0.76	13.52		77	0.76	15.27
125	0.72	13.22		139	0.78	15.13
148	0.70	11.93		102	0.76	13.52
92	0.71	10.48		125	0.72	13.22
20	0.69	10.38		176	0.85	12.54
161	0.67	10.17		148	0.70	11.93
165	0.72	10.10		92	0.71	10.48
129	0.81	10.01		20	0.69	10.38
41	0.71	9.92		161	0.67	10.17
40	0.69	9.81		175	0.73	10.15
53	0.67	9.15		165	0.72	10.10
144	0.71	9.12		129	0.81	10.01
-	-	-		-	-	-
59	0.39	2.10		59	0.39	2.10
75	0.50	2.03		75	0.50	2.03
123	0.47	2.01		123	0.47	2.01
110	0.30	1.98		110	0.30	1.98
48	0.34	1.93		48	0.34	1.93
88	0.19	1.92		88	0.19	1.92
170	0.35	1.91		170	0.35	1.91
109	0.21	1.85		109	0.21	1.85
49	0.41	1.68		49	0.41	1.68
119	0.21	1.67		119	0.21	1.67
155	0.09	1.29		155	0.09	1.29
17	0.50	1.16		17	0.50	1.16
158	0.43	1.13		158	0.43	1.13
51	0.26	1.06		51	0.26	1.06
106	0.02	1.02		106	0.02	1.02
105	0.02	0.96		105	0.02	0.96
150	0.40	0.86		150	0.40	0.86

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