Directions of Development of Human Capital of Innovative Petrochemical Enterprises

Direcciones de desarrollo del capital humano de empresas petroquímicas innovadoras

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Abstract
The main aim of the article is to identify the directions of innovative human capital development of industrial enterprises based on the development of an improved assessment methodology. The object of the research is industrial enterprises of the Russian economy. The subject of the research is innovative activity of the enterprises. The key research method is modeling (building a regression model, production function), which makes it possible to systematically study the links between indicators of enterprise innovation and the use of human capital in this process, as well as identify problem areas and directions of human capital development of industrial enterprises. A systematic approach was also applied, which made it possible to visualize the scheme of human capital development and the impact on the results of the enterprise; a comparative method by which the specificity of the human capital using for each of the studied enterprises is assessed. As a result, a number of new scientific results have been proposed: a scheme of the human capital management in the organization was drawn up, taking into account innovative development guidelines, covering the author's methodology for assessing innovative human capital based on three averaged indicators (coefficient of human capital using, coefficient of ensuring profit by each employee of the enterprise and coefficient of innovative competitiveness), which allow assessing the contribution for each economic entity human capital to enhance innovative competitiveness; a regression model has been developed that reflects the influence of changes in the input variables (the number of employees engaged in R&D and R&D costs) on the resulting coefficient of innovative competitiveness of the studied enterprises; a Cobb-Douglas model based on the calculation of harmonic weighted averages has been constructed, which defines directions for improving the efficiency of human capital use in the innovative activities of industrial enterprises.
Keywords: human capital, innovative human capital, knowledge economy, innovation economy, innovation competitiveness, innovation activity, petrochemical enterprises.

Resumen
El objetivo principal del artículo es identificar las direcciones del desarrollo innovador del capital humano de las empresas industriales sobre la base del desarrollo de una metodología de evaluación mejorada. El objeto de la investigación son las empresas industriales de la economía rusa. El tema de la investigación es la actividad innovadora de las empresas. El método de investigación clave es el modelado (construcción de un modelo de regresión, función de producción), que permite estudiar sistemáticamente los vínculos entre los indicadores de innovación empresarial y el uso del capital humano en este proceso, así como identificar áreas problemáticas y direcciones desarrollo de capital de empresas industriales. También se aplicó un enfoque sistemático, que permitió visualizar el esquema de desarrollo del capital humano y el impacto en los resultados de la empresa; método comparativo mediante el cual se evalúa la especificidad del capital humano utilizado para cada una de las empresas estudiadas. Como resultado, se han propuesto una serie de nuevos resultados científicos: se elaboró un esquema de la gestión del capital humano en la organización, teniendo en cuenta los lineamientos de desarrollo innovador, cubriendo la metodología del autor para la evaluación del capital humano innovador a partir de tres indicadores promediados (coeficiente de utilización de capital humano, coeficiente de aseguramiento de la ganancia por cada empleado de la empresa y coeficiente de competitividad innovadora), que permiten evaluar la contribución de cada entidad económica al capital humano para mejorar la competitividad innovadora; se ha desarrollado un modelo de regresión que refleja la influencia de los cambios en las variables de entrada (el número de empleados dedicados a I + D y costes de I + D) sobre el coeficiente resultante de competitividad innovadora de las empresas estudiadas; Se ha construido un modelo Cobb-Douglas basado en el cálculo de promedios ponderados armónicos, que define direcciones para mejorar la eficiencia del uso del capital humano en las actividades innovadoras de las empresas industriales.
Palabras clave: capital humano, capital humano innovador, economía del conocimiento, economía de la innovación, competitividad de la innovación, actividad de innovación, empresas petroquímicas.

Introduction

The increasing complexity of global economic processes, the regular search for new ways to improve the competitiveness of products and services produced by companies, and a shift in the focus on the innovative potential of human resources make it necessary to develop a management model that is adequate to the realities of the modern economy - the digitalization of microeconomic systems, an increase in the innovative activity of companies, and an awareness of the high value of employee participation in the implementation of the company's development strategy. The dynamic change in the external environment has a direct impact on the course of internal business processes of the enterprise, requires flexibility from personnel, manifested in the ability and willingness to rebuild to new methods of performing tasks, in the knowledge and skills required for adaptation (Levina et al., 2019). As a result, the reaction to the ongoing changes in the macroeconomic environment is the awareness of the need to transform the personnel subsystem, which can ensure the saving of resources for management and production.

Human capital as a complex of competencies is difficult in terms of assessment. Its implementation is associated with scientific and technical, innovation, management, production and other activities that require specific knowledge, skills and abilities. As a result, this type of capital is involved in all processes that transform resources (input) into a product (output) based on control actions and using the necessary equipment, information systems and technologies.

Effective and rational management of human capital is possible on the basis of methodological tools that allow assessing the dynamics of the level of human capital development not only at the macro, but also at the micro level. Taking into account the above, we consider it necessary to search for solutions to the methodological problem and develop a model for effective management of the implementation of human potential.

Literature Review

Human capital is the subject of many scientific studies and is covered in detail from different perspectives.

A number of authors investigate models of human capital management, taking into account regional specifics. The importance of investing not so much in infrastructure as in human capital is disclosed on the example of China in a review article by W.J. Morgan (2013); the problems of the industry of meetings, incentives, conferences and exhibitions (Meeting, Incentive, Convention, and Exhibition, MICE), consisting in the lack of qualified personnel, the lack of integrated interaction of stakeholders, are presented on the example of Malaysia (Adros & Wee, 2019). Develops investment topics S.E. Krauss et al. (2007), analyzing the positive development of youth as an investment object. R.E. Ahmad (2012) reveals an institutional approach that requires taking into account the specifics of local values, formal and non-formal education, as well as a methodology for assessing investment in human capital; the exclusively institutional aspect as a fundamental principle of the formation of effective human capital development is presented in the study by S. Gad et al. (2020).

The problem of organization's human resources development in terms of favorable organizational culture and working conditions was reflected in the studies of S. Mohammadi (2020), M. Mamaghaniyeh, M. Sadeghi and S. Amani (2019). The relationship between human capital development and innovative development is also studied through the prism of environmental issues (Carraro, De Cian & Tavoni, 2014), sectoral development (Jegede et al., 2016; Oliveira & Turčínková, 2019; Kuznetsova et al., 2020), etc.

Extensive attention in the scientific literature is paid to the study of the importance of human capital in innovative economy. The role of knowledge management in the innovative development of organizations and their networks is disclosed in the article by J. Swan et al. (1999). The authors focus on increasing innovation efficiency as a result of knowledge exchange and motivation of this exchange. The influence of the knowledge management system on the managerial skills of managers (perceptual, human and operational) and, as a result, on the innovative activity of the organization was assessed in the work of M. Sabokro, M. Tajpour and E. Hosseini (2018). Studies have also been published on the features of analysis of the innovative development of countries around the world, with a focus on human resources and human capital (Shinkevich et al., 2018; Tolstykh et al., 2020).

As part of our research, we are particularly interested in methodological approaches to the human capital assessing. V.A. Perepelkin and E.V. Perepelkina (2018) based their comparative analysis of human capital in Russia and China on macroeconomic indicators. Key indicators of human capital assessing within a microeconomic system that meet the characteristics of the knowledge economy are presented in the work of N. Jergova and L. Bednarova (2016), but only as a system of criteria. O. Pirogova and V. Plotnikov (2019) proposed the complex cost estimation of the company's personnel, which summarizes the current and future components. Moreover, capacious methodological toolkit developed by the UN and presented in the form of a guide containing various approaches to human capital measuring (United Nations Economic Commission for Europe. Guide on Measuring Human Capital, 2016).

The conducted analytical review testifies to both the relevance of the problem under study and the high interest of scientists and practitioners in the issues of effective human capital management. At the same time, despite the extensive theoretical and methodological array of studies, we come to the conclusion that not enough attention is paid to human capital assessing at the micro level, the impact of the level of use of innovative human capital on the competitiveness of an enterprise.

Description of Data

In order to standardize of the human capital assessment at the global level, a ranking of countries according to the Human Capital Index is published annually (HCI). The indicator is of a macroeconomic nature, takes into account social factors of development and their impact on labor productivity in the country's market economy. Based on the Index, a comparative analysis of countries is carried out (174 countries according to the 2020 rating), which contributes to the identification of underdeveloped areas of society, the strategic importance of investing in the country's human capital is noted. Table 1 shows the values of the Index and the rating in the context of the countries included in the estimated sample.

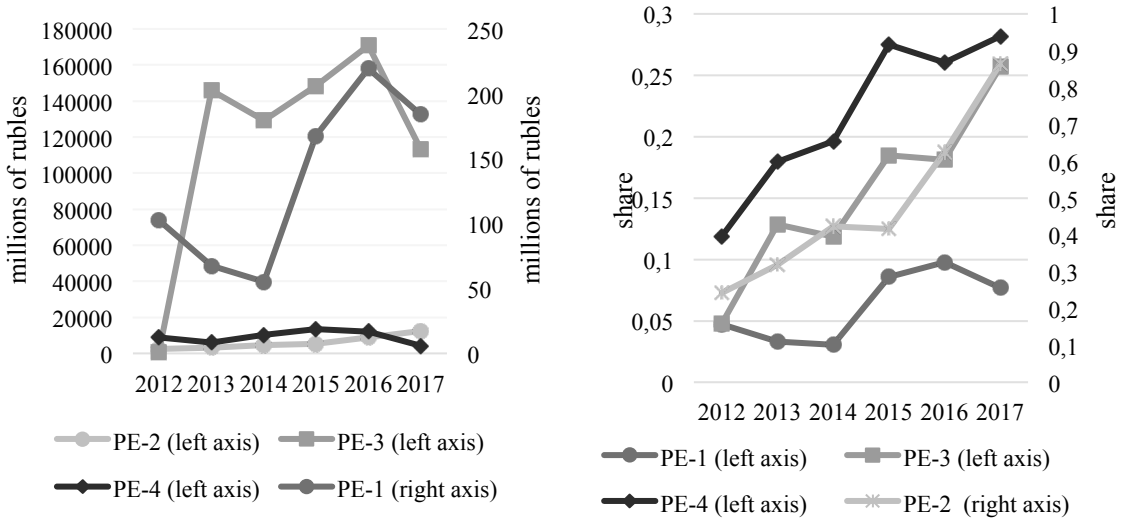
Table 1. Ranking of countries by the level of the Human Capital Index (World Bank, 2020)

Economy	HCI 2020	HCI 2010
Singapore	0.88	0.85
Hong Kong SAR, China	0.81	0.78
Japan	0.80	0.82
Korea, Rep.	0.80	0.82
Macao SAR, China	0.80	0.65

Sweden	0.80	0.76
Netherlands	0.79	0.80
United Kingdom	0.78	0.77
Estonia	0.78	0.73
…		
Russian Federation	0.68	0.60
…		

However, the management of human capital development is a hierarchically structured mechanism that requires, first of all, global optimum, represented by global indices. Our research focuses on assessing the use and development of human capital within petrochemical enterprises. At a certain stage of the study, indicators were selected that characterize the microeconomic capital management, similar to the search for local optima, which, as a result, ensure the achievement of a dynamics of innovative development for four enterprises in 2012-2017.

At the first stage, the dynamics of indicators characterizing the "exit" in the cybernetic system of the enterprise was assessed (fig. 1).



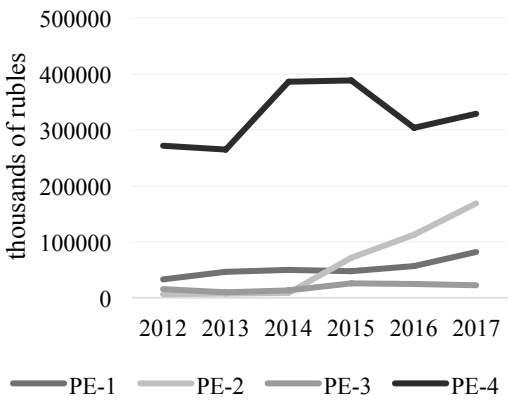
a) Change in the volume of shipped innovative products

b) Change in the share of innovative products

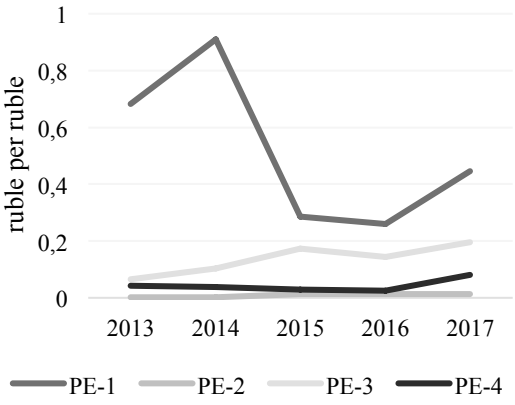
Figure 1. Dynamics of the effectiveness of innovative activities of four petrochemical enterprises of the Republic of Tatarstan (built by the author)

In value terms, fluctuations in the dynamics of innovative products are more obvious and intense, with the exception of the PE-2 enterprise, for which we observe a stable growth of the indicator. On the other hand, the intensification of research activities of enterprises is obvious, since the share of innovative products is growing in all four cases.

At the next stage, R&D expenditures were estimated, both in value terms and per 1 ruble of shipped innovative products (Fig. 2). Comparing the graphs, on the one hand, we see significantly high investments of the PE-4 enterprise in R&D relative to the other three enterprises. On the other hand, unit costs prevail in the PE-1 enterprise (in dynamics they decreased by 34%) and are low in the PE-4 enterprise. That is, given the scale of the PE-4 enterprise, it can be argued about its effective innovation. The highest growth rate of costs is observed for the PE-2 enterprise - a 27-fold increase in the indicator over 6 years.



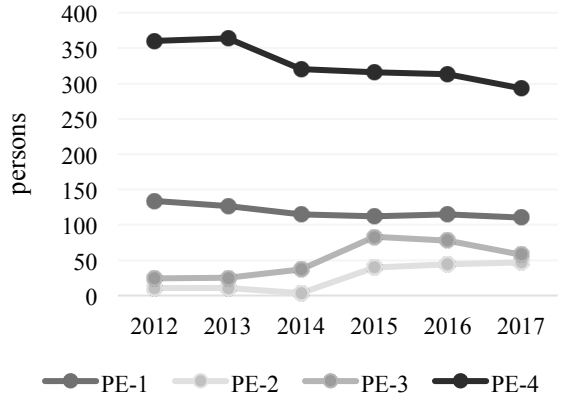
a) Changes in the level of research and development costs



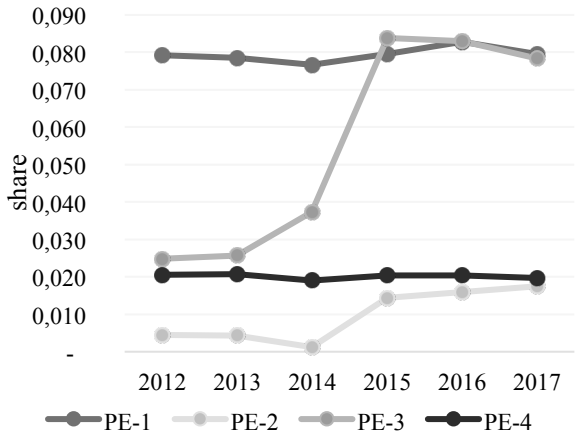
b) Change in R&D costs per 1 ruble of shipped products

Figure 2. Dynamics of indicators of costs for innovative activities of four petrochemical enterprises of the Republic of Tatarstan (built by the author)

Finally, the most important stage of the study is the realization of human potential in the innovation process of enterprises (fig. 3). The object of our research is innovative human capital - generators of innovations at an enterprise, employees with a set of competencies for carrying out research activities at an enterprise. Comparing with the indicators discussed above, the high level of the number of employees in the field of R&D at the PE-4 enterprise seems logical, but at the same time, the share of these employees in the total number of employees is small in comparison with the enterprises PE-1 and PE-3. The latter demonstrates a sharp increase in the share of researchers in 2015 by 125%, which was accompanied by an increase in the share of innovative products by 12% (Fig. 1b), an increase in unit R&D costs by 67% (Fig. 2b), which indicates a positive effect of changes in the structure of the enterprise staff. In addition, at this enterprise for the period 2014-2015, there was a decrease in the average number of employees by 3 people and a simultaneous increase in the number of people employed in R&D by 46 people. This confirms the qualitative changes in the personnel structure of the PE-3 enterprise towards innovative development.



a) Change in the number of workers engaged in research and development



b) Change in the share of employees engaged in research and development in the average number of employees of the enterprise

Figure 3. Quantitative change in the innovative human capital of petrochemical enterprises of the Republic of Tatarstan (built by the author)

In general, an analytical study of the main indicators of innovation activity of four petrochemical enterprises, including the realization of human potential, proves the positive aspect of attracting employees to R&D. This is manifested in a decrease in unit costs for research and development, an increase in the share of innovative products. However, profit does not always increase, which can be considered as insufficient rational use of resources and human capital, which requires a

systematic approach to measuring the aggregate qualitative result of enterprises' innovative activities.

Methodological Framework

Research and modeling of human capital development management at the micro level was carried out in three stages:
1) the development of a scheme of human capital management at an enterprise, taking into account innovative development guidelines, based on the calculation of three coefficients that allow us to evaluate the human capital of an enterprise and its impact on the resulting performance indicators;
2) based on the proposed coefficients, the construction of an economic and mathematical model in the form of a multiple regression equation;

3) the construction of the Cobb-Douglas production function, which allows to determine the directions of increasing the efficiency of attracting human capital to the innovative activities of petrochemical enterprises.
Regression analysis is aimed at finding a qualitative model that is adequate to the real conditions of the functioning of enterprises, which makes it possible to reveal the dependence of the studied variables and has the form:

$$y = a + b*x_1 + c* x_2. \quad (1)$$

The quality assessment of the model is traditionally carried out according to the coefficient of determination, which reflects the percentage of the obtained model describes the actual features, Fisher's F-criterion, Student's t-criterion. The construction of the model is carried out by means of the Statistica software product.
The classical two-factor Cobb-Douglas model in our case is aimed at describing the dependence of the output parameters of the enterprise innovation process on labor and capital costs for R&D. In general, the production function is:

$$Y = a_0*K^{a1}*L^{a2}, \quad (2)$$

where Y – average volume of innovative goods and services per 1 employee engaged in research and development (calculated by the method of weighted average harmonic), thousand rubles;
K – average level of research and development costs per 1 employee engaged in research and development (calculated using the method of weighted average harmonic), thousand rubles;
L – the average number of employees who performed research and development (calculated using the arithmetic mean method), people;

a_0 – neutral technical progress ratio;
a_1 – coefficient of elasticity of the variable K;
a_2 – coefficient of elasticity of the variable L.
To construct the production function, MS Excel tools were used, as well as logarithm of features, the use of the LINEST function to calculate a set of statistics, an assessment of the quality of the Cobb-Douglas model by comparing the calculated and tabular values of the Fisher criterion (and recognizing the model as qualitative in case of exceeding the calculated over tabular).

The model assumes the possibility of identifying ways to improve the efficiency of innovative human capital at petrochemical enterprises.

The study used a set of data characterizing the innovative activities of four petrochemical enterprises of the Republic of Tatarstan:
P_{total} – average number of employees of the enterprise, people;
$P_{R\&D}$ – number of employees engaged in R&D, people;
Q_{innov} – volume of shipped innovative goods, works, services, million rubles;
d_{innov} – share of innovative goods, works, services in the total volume of shipped goods of own production;
$C_{R\&D}$ – research and development costs, thousand rubles;
NP – net profit of the enterprise, million rubles;
t – observation period (year).

Results and Discussions

A Scheme of Human Capital Management of Organization Has Been Built, Taking Into Account Innovative Development Guidelines, And Indicators Reflecting The Use of Innovative Human Capital Have Been Evaluated (In Accordance With The Author's Methodology)

Effective and rational management of human capital in an innovative economy is not typical for all enterprises of the petrochemical sector that carry out various kinds of innovations. As part of the study, an assessment of the correlation between the number of research personnel and the volume of shipped innovative products and services was carried out (table 2).

Table 2. Correlation of indicators of innovative development of petrochemical enterprises of the Republic of Tatarstan

Petrochemical enterprises	r ($P_{R\&D}$; Q_{innov})	r ($P_{R\&D}$; d_{innov})

PE-1	-0,539030843	-0,564598369
PE-2	0,818153277	0,762325839
PE-3	0,588250143	0,411630675
PE-4	-0,094458466	0,140877331

Despite the high volume of innovation activity, a number of petrochemical enterprises demonstrate a weak link between the staff of research personnel and the production and sale of innovative products. leads to low rates of closeness of the relationship between the selected variables. A quantitative approach to the formation of effective innovative human capital is observed only for one petrochemical enterprise - PE-2.

Note that this study is based on the proposition that human capital is a key object of management in an innovative economic system of any level. It is directly related to the volume of innovative activity and the level of innovative activity, as a result of which the integrated management of the

As a result, it can be argued that the qualifications of personnel engaged in research and development are significantly differentiated and, in turn,

implementation of human potential contributes to the growth of profits, an increase in the efficiency of the enterprise and an increase in competitiveness in the market space. By investing in human resources, an organization reveals and implements human potential, which determines the success of an economic entity as a result (fig. 4). Since attention is focused on the scientific and technical development of the microeconomic system, we consider it necessary to clarify that the study is focused on assessing innovative human capital.

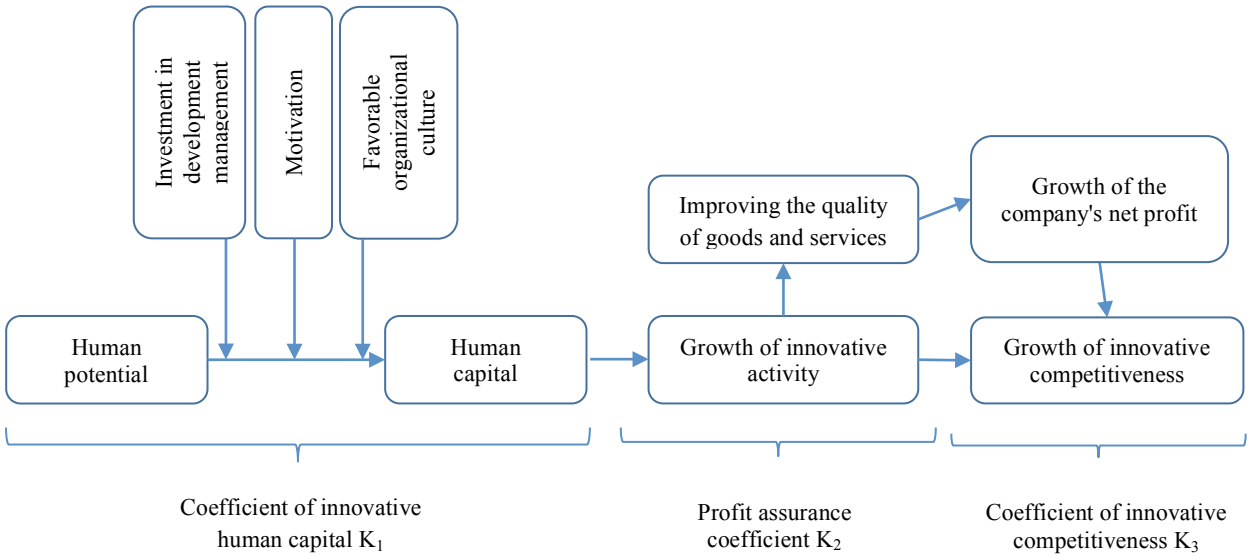


Figure 4. Scheme of the human capital development and the impact on the results of the enterprise

To calculate the Ki coefficients, it is proposed to use the harmonic weighted average. As a result, we propose to calculate the coefficient of innovative human capital K_1 as the ratio of the weighted average result per 1 employee engaged in R&D to the weighted average costs related to the number of personnel engaged in R&D for a number of years under study:

$$K_1 = \frac{\sum_{i=1}^{t} Q_{innov(i)}}{\sum_{i=1}^{t} \frac{Q_{innov(i)}}{P_{R\&D(i)}}} / \frac{\sum_{i=1}^{t} C_{R\&D(i)}}{\sum_{i=1}^{t} \frac{C_{R\&D(i)}}{P_{R\&D(i)}}} . \quad (3)$$

Profit assurance coefficient K_2 is calculated for the enterprise as a whole, but it is averaged including for employees engaged in R&D:

$$K_2 = \frac{\sum_{i=1}^{t} NP_{(i)}}{\sum_{i=1}^{t} \frac{NP_{(i)}}{P_{total(i)}}} . \quad (4)$$

And finally, the resulting indicator - the coefficient of innovative competitiveness K_3 - is determined as the weighted average cost of R&D per 1 ruble of shipped innovative products of the enterprise:

$$K_3 = \frac{\sum_{i=1}^{t} C_{R\&D(i)}}{\sum_{i=1}^{t} \frac{C_{R\&D(i)}}{Q_{innov(i)}}} . \quad (5)$$

In order to determine the influence of innovative human capital on the competitiveness of an enterprise, we calculated the harmonic averages, which formed the basis for measuring the utilization rate of human capital (K_1), the coefficient of ensuring profit by each employee of the enterprise on average (K_2) and the resulting coefficient of innovative competitiveness (K_3) in the context of petrochemical enterprises of the Republic of Tatarstan (table 3).

Table 3. Indicators for building a model for managing the development of innovative human capital of petrochemical enterprises of the Republic of Tatarstan (calculated by the authors)

Petrochemical enterprises	The result of human capital using	The cost of human capital using	Human capital ratio (K_1)	Profit assurance ratio (K_2)	Innovative competitiveness coefficient (K_3)
PE-1	116,172	116,473	0,997	1,539	0,109
PE-2	14,130	31,175	0,453	2,690	775,391
PE-3	46,349	46,419	0,999	0,976	0,024
PE-4	325,347	323,361	1,006	15,823	223,037

According to the calculated indicators, the most effective result (productivity) of human capital (K_1) was shown by the PE-4 enterprise, the lowest - by the PE-2 enterprise. In accordance with the results (table 3), we can argue that the second petrochemical enterprise is characterized by a quantitative approach to increasing innovation activity, namely, by attracting research personnel. At the same time, judging by the values of the profit guarantee ratio (K_2), the highest profit is brought by each employee of the PE-4 enterprise, where the number of this category of personnel is relatively high (fig. 3a). The ratio of research and development costs to the result in the form of the volume of shipped innovative goods, works and services (K_3) also allows us to designate the high innovative efficiency and competitiveness of the PE-2 petrochemical enterprise. The indicators of enterprises PE-1 and PE-2 are distinguished by a relatively low level, which requires diagnostics and reengineering of the innovation process implemented at these two enterprises.

A Reliable Economic and Mathematical Model has Been Built, Reflecting the Influence of the Level of Use of Human Capital on the Innovative Competitiveness of Petrochemical Enterprises

On the basis of the calculated coefficients K_i for the indicators of innovation activity of petrochemical enterprises, an adequate regression model has been built that describes the dependence of the coefficient of innovative competitiveness K_3 on the indicators of the efficiency of using human capital K_1 and K_2. Regression statistics (table 4) contains information about the value of the coefficient of determination (RI = 0.99986317), which tends to 1, i.e. the constructed regression model describes the investigated dependencies quite fully. The adequacy of the equation is confirmed by Fisher's *F*-statistic, which is 3653.8 with a significance level of *p* below 0.01170, as a result of which it can be argued that the null hypothesis is refuted.

Table 4. Regression statistics on indicators for assessing the use of human capital by petrochemical enterprises of the Republic of Tatarstan.

	Regression Summary for Dependent Variable: Y R= ,99993158 RI= ,99986317 Adjusted RI= ,99958952 F(2,1)=3653,8 p<,01170 Std.Error of estimate: 7,4137					
	b*	Std.Err.	b	Std.Err.	t(1)	p-value
Intercept			1358,05	14,00872	96,9429	0,006567
x1	-1,03306	0,012098	-1380,88	16,17153	-85,3895	0,007455
x2	0,31078	0,012098	16,06	0,62528	25,6886	0,024770

Based on the results of a qualitative assessment of the constructed economic and mathematical model of human capital management of petrochemical enterprises of the Republic of Tatarstan, it is advisable to present the regression equation:

$K_3 = 1358{,}05 - 1380{,}88*K_1 + 16{,}06*K_2$,
where K_1 – human capital utilization rate;
K_2 – coefficient of ensuring profit by employees of the enterprise;
K_3 – resulting coefficient of innovative competitiveness.

The coefficients of the regression equation confirm the high importance of research personnel for the innovative activity and competitiveness of enterprises in the industry, as evidenced by the coefficient b_1 = - 1380.88 - the best predictor of the constructed model. Significantly less influence is exerted by the indicators of net profit brought on average by each employee of the enterprise,

including those engaged in research and development.

In general, the model is recommended to be used in planning and forecasting the staff of research personnel, the cost of innovation. As a result of testing the model, it was revealed that an increase in the number of employees engaged in R&D, research and development costs and the volume of shipped products by 1% give a different nature of changes for the enterprises under study. In this regard, a differentiated approach is required to highly competitive enterprises (with a high level of the K_3 coefficient) and low competitive in terms of the use of human capital. In the case of enterprises PE-2 and PE-4 (highly competitive enterprises), a higher growth rate is recommended, since the economic system has high potential. At enterprises PE-1 and PE-3, stimulation of innovative activity is required (table 5).

Table 5. Estimated indicators of the human capital using with a potential increase in the initial variables (calculated by the authors)

Petrochemical enterprises	The result of human capital using	The cost of using human capital	Human capital ratio (K_1)	Profit assurance ratio (K_2)	Innovative competitiveness coefficient (K_3)
Increase in the number of research personnel by 5% Increasing research and development costs by 5% Assumption of an increase in the volume of shipped innovative goods and services by 5%					
PE-1					
fact	116.172	116.473	0.997	1.539	0.109
calculation	116.04	116.263	0.998	1.539	□ 4.536
PE-3					
fact	46.349	46.419	0.999	0.976	0.024
calculation	48.0	48.418	0.991	0.976	□ 4.776

Thus, the proposed model is a complex economic and mathematical mechanism for managing innovative human capital, which makes it possible to assess the influence of input numbers (the number of employees engaged in R&D and R&D costs) on the resulting coefficient of innovative competitiveness of the studied petrochemical enterprises. Optimization model for microeconomic systems and can be adapted for enterprises in the economic sphere, which can be an advantage in the form of versatility.

The Cobb-Douglas Production Function was Built, Based on the Calculation of Harmonic Weighted Averages, and Determining the Directions for Increasing the Efficiency of Attracting Human Capital to the Innovative Activities of Petrochemical Enterprises

This study is expanded by constructing a production function that provides opportunities for modeling labor and capital investments in the innovative development of petrochemical enterprises. The peculiarities of the proposed model consist in calculating the harmonic weighted averages for a number of periods (2012-2017) in the context of petrochemical enterprises, which compensates for the lack of a static production function formed by the totality of the studied economic entities. In this regard, the analysis includes: the average volume of innovative goods and services per 1 employee engaged in research and development; the average level of research and development costs per employee of the corresponding structural unit; the average number of employees who performed research and development.

The proposed model for managing innovative human capital of petrochemical enterprises of the Republic of Tatarstan is as follows:

$$Y = 0{,}502 * K^{-1{,}668} * L^{2{,}787},$$

where Y – average volume of innovative goods and services per 1 employee engaged in research and development (calculated by the method of weighted average harmonic), thousand rubles;

K – the average cost of research and development per 1 employee engaged in research and development (calculated using the method of average harmonic weighted), thousand rubles;

L – average number of employees who performed research and development (calculated using the arithmetic mean method), people.

The constructed Cobb-Douglas production function was estimated by Fisher's *F*-criterion by comparing the tabular and calculated *F* values:

F-criterion (calc.) = 186,54 > F-criterion (tab.) = 138,39.

The deviation of the actual data from the calculated ones is insignificant, the model describes the initial data by 94%. We recognize the resulting model as adequate to the actual characteristics in the dynamic picture of the effectiveness of the use of innovative human capital. Judging by the coefficients of the equation, it can be judged that capital investments

were not used effectively enough at the studied enterprises for the analyzed period, as evidenced by the negative coefficient of elasticity with the factor "capital". At the same time, an increase in research and development costs per 1 employee engaged in research and development by 1% will lead to a decrease in *Y* by 1.668%. With regard to human capital, the elasticity coefficient of 2.777 reflects an increase in the volume of shipped innovative goods and services per 1 worker engaged in research and development by 2.787%, while the number of workers performing research and development by 1% increased. In general, assessing the nature of innovation and the participation of human capital, it is necessary to note the growing innovation activity. This is due to the fact that the sum of the elasticity coefficients equal to 1.11 exceeds 1, i.e. the return on capital and labor investments in the innovative development of petrochemical enterprises is still increasing. The growing innovative activity is labor-intensive, which determines the need to harmonize the two factors of the model and the transition to qualitative development, rather than quantitative.

Thus, the constructed economic and mathematical model can be recommended to enterprises of the petrochemical industry as a mechanism for managing innovative development and efficient and rational use of the enterprise's human capital. Despite the low-efficiency capital investments per 1 employee engaged in R&D, we believe that the awareness of industrial enterprises of the value of realizing human potential and developing human capital can provide a significant impact on increasing the innovative competitiveness of an enterprise and its products.

The modeling results presented in the work reflect the hidden links between the economic result of the activities of petrochemical enterprises, innovative development and human capital and are practically significant from the point of view of the management mechanism of the microeconomic system. A systematic approach to monitoring indicators, the proposed ratios of the use of human capital, the coefficient of ensuring profit by each employee of the enterprise on average and the resulting coefficient of innovative competitiveness presents an opportunity for the enterprise to increase the efficiency of innovation.

Findings

This study is based on data from four petrochemical enterprises (depersonalized due to confidentiality of information). In the future, it is planned to expand both the time series of data and the number of enterprises under study, to move from the mesoeconomic level to the macroeconomic one. In addition, enterprises are interested in investing in the development and professional development of R&D workers. Analytical research, economic and mathematical modeling made it possible to identify an ambiguous trend characterizing the innovative development of petrochemical enterprises and the role of human capital in this process. It has been determined that in development, human capital investment prevails over capital investment. In our opinion, this trend contradicts harmonized economic development, when enterprises need not only to attract additional employees, but to effectively invest in their development within the framework of R&D costs. Otherwise, the costs of research and development are spent irrationally, which is confirmed by the construction of the Cobb-Douglas model. For some of the studied enterprises, as shown by the study, a positive effect is characteristic as a result of quantitative changes (attracting personnel), for other enterprises an increase in competitiveness is typical due to an increase in the quality of innovative products as a result of additional costs. In this regard, enterprises focused on increasing the economic efficiency of their activities need to realize the rational implementation of human potential. Thus, the conducted research is not limited to only three coefficients and can be supplemented by other indicators that allow to take into account more fully the factors influencing the implementation of the human capital of enterprises.

Conclusion

Human capital is the central link of both the national innovation system and microeconomic systems focused on opening their own "blue" oceans, providing high profits through the development and sale of science-intensive, demanded and affordable goods and services. This effect can be achieved through the realization of human potential and the development of human capital, since an employee with a set of valuable competencies and creative thinking is a key generator of innovations of interest to the consumer.

On the basis of the literature review of the results of scientific research carried out in Russia and abroad, the extensiveness of the study of this problem is shown. The focus is on the features of management and development of human capital at the macro and micro levels, social aspects, institutional approach, etc. A number of studies are exclusively theoretical and methodological in nature, which makes it difficult to apply the results in practice. At the same time, the UN has published a guide to measuring human capital, which includes a set of different assessment methods, but at the country level. We consider it necessary to clarify the existing

approaches in relation to an enterprise (namely, a petrochemical one), within the framework of which a number of new scientific results have been obtained:

1) proposed a scheme for managing human capital in an organization, taking into account innovative development guidelines, covering the author's methodology for assessing innovative human capital based on three averaged indicators: the coefficient of human capital utilization (K_1), the coefficient of ensuring profit by each employee of the enterprise on average (K_2) and the resulting coefficient of innovative competitiveness (K_3) in the context of petrochemical enterprises of the Republic of Tatarstan; the indicators are assessed for each economic entity and reflect the differentiated contribution of human capital to increasing innovative competitiveness;
2) a reliable economic and mathematical model has been developed that reflects the effect of changes in input variables (the number of employees engaged in R&D and R&D costs) on the resulting coefficient of innovative competitiveness of the studied petrochemical enterprises;
3) the production function of Cobb-Douglas is built, based on the calculation of harmonic weighted average, and determining the directions of increasing the efficiency of using human capital in the framework of innovative activities of industrial enterprises.
According to the results of the study, it is proposed: rationalization of investment in R&D, which at the current stage is not effective enough; focus on the qualitative development of innovative human capital of petrochemical enterprises.

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