

The Impact of Human Capital on the Efficiency of Technological Innovation Application

V S Zharov^{1,2}

¹Branch of the Murmansk Arctic State University in Apatity, 184209, 29 Lesnaya St., Apatity, Russia

²Institute of Economic Problems named after G.P. Luzin, Kola Science Center, Russian Academy of Sciences, 184209, Fersman St. 24a, Apatity, Russia

E-mail: zharov_vs@mail.ru

Abstract. A problem of giving a quantitative evaluation of how the human capital affects the level and dynamics of the innovation-driven technological development of economic production systems of various levels, including manufacturing enterprises, has not yet been expressly solved. This fact lowers the scientific validity level of strategies for the technological development of a country, regions, branches of economy and individual enterprises. The objective of this work is to develop a framework methodology for such an evaluation to be applied at manufacturing enterprises, which is based on a new theoretical and methodological foundation of the investment and innovation analysis of production systems performance. To this end, it is proposed, first, to identify three levels of human capital management. Second, to calculate the values of the proposed factor of the produce-ability level as the material productivity to capital productivity ratio for a number of enterprises operating in the same industry and for each management level. Third, for each of the three enterprise management levels, to conduct a survey and hold an opinion poll to determine the significance (importance) rating of each of the main human capital factors that influence the innovation-driven technological development. The methodology will help, first, to assess the composite index of the enterprise human capital at different levels of its involvement in terms of its impact on the implementation of technological innovations. Second, to estimate the efficiency of human capital management at the enterprises at different levels of its involvement. Third, to evaluate the efficiency of the enterprise innovation in the field of the involved human capital. Fourth, to shape the requirements for the human capital quality improvement both internally (enterprise) and externally (educational system).

1. Introduction

Human capital accounts for more than half of the national wealth of any country and is the key development factor of a knowledge-based innovation-driven economy. Back in the 1980s, in his models reflecting the endogenous growth theory, Paul M. Romer, a co-recipient of the Nobel Prize in Economics in 2018, established the primacy of technological progress in accounting for long-term economic growth in the world economy, the pace of which is determined, on the one hand, by investments into research and development and, on the other, by investments into human capital [1, 2]. However, in practice, the relation between the economic growth rate and these two factors at macro, meso- and micro levels is still not defined quantitatively, which makes it impossible to develop any

scientifically grounded strategies for technological development of the country, regions, branches of economy and individual enterprises, which is the most important task of the modern economy in Russia.

Numerous foreign publications on the evaluation of the human capital impact on performance of the individual economic systems of various levels and scope, including individual firms, always emphasize *there being* such an impact [3,4,5], however, they do not propose any definable quantifying indicators. Furthermore, the main efforts of this discipline are focused on subdividing the intellectual capital into human, structural and relational (market), and studying their individual influence on competitiveness and profitability of organizations and firms by processing the acquired expert data or social research data using mathematical statistics methods [6, 7, 8]. A number of publications note that the human capital directly affects the efficiency of involving structural capital and the enhancement of drastic and incremental innovations [9, 10] not only in large, but also in small and medium-sized businesses, though, as a rule, this fact is presented only as generic observations [11, 12].

Research on the human capital studies conducted in Russia in the recent years is mainly focused on developing certain methods and techniques for evaluating the level of human capital at the macro and micro levels of economic systems [13], though no comprehensive technique has yet been developed [14], making the efficient human capital management impossible. That said, many scientists point out that human capital holds a prominent place in the innovation-driven economy model of the country [15, 16] and has a marked impact on improving competitiveness of any enterprise [17, 18] and the focus on innovation in its development [19, 20]; however, they do not propose any definable indicators for evaluating this impact, not least because of the lack of the necessary statistics. Consequently, each case study proposes and uses various techniques of mathematical statistics to evaluate the impact of human capital on the activities of certain organizations as a whole [21] without subdividing them into the levels of such capital management. Moreover, in our opinion, this discipline underestimates the role of social research.

It should be noted that up to the present day, the problem of estimating the efficiency of applying technological innovations remains understudied, therefore, this estimate is rarely used in innovation management, including in the development of innovation strategies. In the current environment of foreign countries and Russia, a diversified indicator framework is used to represent the innovation level of technological development in production systems [22, 23, 24], including the research and development expenses, the number of patents obtained, the share of sales of innovation-based goods in the total sales amount, the number of new technologies that were developed and implemented, etc.

In recent years, a number of research focused on the development of the indicators framework for evaluating the technological development level of economic systems, mainly of macro and meso-levels, has been increasing [25], however, for this purpose, it is ultimately proposed to develop various composite indexes. The obtained result depends, accordingly, on the type and number of sub-indexes, factors or indicators chosen for the cumulative index estimation, as well as on the signification (weight) of each of them, which is defined on a subjective basis.

2. Research design

Thus far, globally, the problem of choosing one or several interrelated indicators for managing the application of technological innovations at macro, meso- and micro levels has not been solved neither in theory nor in practice. Moreover, the problem of evaluating the human capital impact on the level and dynamics of the innovation-driven technological development of economic production systems of various levels, including manufacturing enterprises, remains unsolved as well.

We have developed a framework for *a new line of economic analysis* of the industrial enterprises activities and industries operation – *an investment and innovation line of analysis*, in terms of which we introduce into scientific use and articulate the *new* concepts of investment and innovation gearing and the produce-ability level factor and define the analytical relation between the indicators of capital/output ratio of production, materials/output ratio of products and labor productivity. Thereupon, we developed a matrix of technological growth options of enterprises, depending on the

efficiency of production resources use, such as labor and physical resources, as well as physical capital represented by fixed assets [26]. We have also produced a graphic model of technological development life cycle of enterprises [27], which uses the changes in indicator values to determine the stage of technological development, as well as the need and possibility of transitioning into the ultimate stage, when there is an increase of material productivity, capital productivity and labor productivity values in equal measure. The produce-ability level factor, which is expressed as the ratio of production capital intensity to its material intensity, is the main indicator [28].

3. Results and discussion

An increase in the value of this factor depends mainly on the extent of replacement of the active part of enterprise fixed assets (machinery, equipment, vehicles), i.e. technically, on the level of knowledge invested in new equipment production and technology promotion, but it is obvious that the performance efficiency of the enterprise management system staff, that is, *human capital*, should also influence this change. At microeconomic level of individual enterprises, this means that apart from the key objective factor of technological progress – technological innovations – there is also the main subjective factor: *the efficiency level of managing the application of such innovations*, that is, the level of knowledge, qualifications and experience not only of the employees, but also of the operating personnel servicing machinery and equipment. At the upper-level of enterprise management (top management), this factor is reflected in the fact that the enterprise management either makes a correct assessment or fails to estimate objectively the need for a timely technological renovation of production. At the secondary level (managers and specialists in the structural divisions of the enterprise), the influence of human capital management efficiency will be reflected in maximization of the resource use of the existing production technology through its improvement. At the lowest level (site managers, crew leaders and even personnel servicing individual units of machinery and equipment) such influence will be reflected in the compliance with process discipline, which ensures a trouble-free technological process, and in providing the opportunities for its improvement through work-improvement suggestions. These considerations allow for the economic assessment of the damage by the production cost increase and reduction of profits as a result of inefficient *human capital management* at any level of the enterprise and for the definition of an approach to evaluating the *efficiency of investments* in such capital.

Therefore, to evaluate the impact of the enterprise human capital on the efficiency of its innovation-driven technological development, it is proposed, first, to identify three levels of human capital management (by the scale of production in large and medium-sized enterprises). Second, using a suitable technique, to calculate the values of the produce-ability level factor for several enterprises operating in the same industry and for each management level over a number (at least three) of identical periods. Third, for each of the three enterprise management levels, to conduct a survey and hold an opinion poll to determine the significance (importance) rating of each of the main human capital factors that influence innovation-driven technological development (knowledge, qualifications, experience), followed by a computation of the average or weighted average value of this rating for a group of enterprises operating in the same industry. Fourth, to calculate the composite index of human capital for each enterprise and management level thereupon. Fifth, using the correlation analysis for the examined enterprises of the same industry and for each management level, to determine the strength of relationship between the values of the produce-ability level factor and the composite index of human capital, as well as its individual components. Sixth, should the desired relationship be found and the deficiencies in the human capital management be identified, to produce the recommendations on improving the efficiency of human capital involvement and present them to the management of the enterprises (improving personnel policy, labor remuneration, occupational retraining and so on). Seventh, to shape the requirements for improving the system of higher, specialized secondary and basic vocational education in the region based on the business demand for improving the human capital efficiency (changing the structure of disciplines, improving quality of training, increasing the number of personnel undergoing retraining and advanced training, etc.).

Development of methodology for evaluating the human capital impact on the innovation-driven technological development of industrial enterprises will help, first, to evaluate the composite index of the enterprise human capital at different levels of its involvement in terms of the effect on the technological innovations implementation. Second, to quantitatively define the level of influence of the enterprise human capital, by individual levels of its involvement, on the innovation-driven technological development of enterprises, on the increase of their performance efficiency and improvement of their competitiveness. Third, to estimate the human capital management efficiency at the enterprises at different levels of its involvement. Fourth, to evaluate the efficiency of the enterprise investment in the human capital. Fifth, to shape the requirements for the human capital quality improvement both internally (enterprise) and externally (educational system).

4. Conclusion

1. It is shown that the problem of evaluating the impact of the human capital on the level and dynamics of the innovation-driven technological development of economic production systems of various levels, including manufacturing enterprises, still remains unsolved.

2. A framework methodology was developed for such an evaluation to be applied at manufacturing enterprises, which is based on a new theoretical and methodological foundation of the investment and innovation analysis of production systems performance.

3. Such a methodology will make it possible to evaluate the composite index of human capital of an enterprise at individual levels of its involvement in terms of the influence on the technological innovations implementation and to shape the requirements for the human capital quality improvement both internally (enterprise) and externally (educational system).

References

- [1] Romer P 1986 Increasing Returns and Long-Run Growth *Journal of Political Economy* vol 94 5
- [2] Romer P 1990 Endogenous Technical Change *Journal of Political Economy* vol 98 5 pp 71-102
- [3] Alpkın L, Bulut C, Gunday G, Ulusoy G and Kilic K 2010 Organizational support for intrapreneurship and its interaction with human capital to enhance innovative performance *Management Decision* vol 48 5 pp 732-755
- [4] Bornay-Barrachina M, López-Cabrales A and Valle-Cabrera R 2016 How do employment relationships enhance firm innovation? The role of human and social capital *The International Journal of Human Resource Management* vol 28 9 pp 1-29
- [5] Cabello-Medina C, López-Cabrales Á and Valle-Cabrera R 2011 Leveraging the innovative performance of human capital through HRM and social capital in Spanish firms *The International Journal of Human Resource Management* vol 22 04 pp 807-828
- [6] Subramaniam M and Youndt M A 2005 The influence of intellectual capital on the types of innovative capabilities *Academy of Management Journal* vol 48 3 pp 450-463
- [7] Wu S H, Lin L Y and Hsu M Y 2007 Intellectual capital, dynamic capabilities and innovative performance of organizations *International Journal of Technology Management* vol 39 3 pp 279-296
- [8] Yam R C, Lo W, Tang E P and Lau A K 2011 Analysis of sources of innovation, technological innovation capabilities, and performance: an empirical study of Hong Kong manufacturing industries *Research Policy* vol 40 3 pp 391-402
- [9] Lara Agostini, Anna Nosella 2017 Enhancing radical innovation performance through intellectual capital components *Journal of Intellectual Capital* 18 Issue 4 pp 789-806 <https://doi.org/10.1108/JIC-10-2016-0103>
- [10] Delgado-Verde M, Martín-de Castro G and Amores-Salvado J 2016 Intellectual capital and radical innovation: exploring the quadratic effects in technology-based manufacturing firms *Technovation* vol 54 pp 35-47
- [11] Agostini L and Nosella A 2016 The central role of a company's technological reputation in

- enhancing customer performance in the B2B context of SMEs *Journal of Engineering and Technology Management* vol 42 pp 1-14
- [12] Agostini L, Nosella A and Filippini R 2017 Does intellectual capital allow improving innovation performance? A quantitative analysis in the SME context *Journal of Intellectual Capital* vol 18 **2** pp 400-418
- [13] Tuguskina G N 2015 Comparative analysis of methods and indicators for assessing the human capital of enterprises *Modern management technologies* **6(54)** pp 61-70
- [14] Rudakov D V, Akhmetova G Z, Makovetsky M Yu 2018 Human capital as a key factor in influencing the performance of Russian space industry enterprises *Economics: yesterday, today, tomorrow* vol 8 **10A** pp 40-48
- [15] Rudakov D V, Akhmetova G Z 2017 Managing intellectual and creative human capital as a condition for the formation of an innovative economy *Management of economic systems: electronic scientific journal* **8(102)** p 9
- [16] Grechko M V 2016 Human capital in the innovative development model of Russia: monograph (Rostov-on-Don: Southern Federal University) 258 p
- [17] Kiseleva N V 2016 Human Resource Management as a Factor of Increasing Enterprise Competitiveness *Management and Business Administration* **1** pp 134-139
- [18] Blagoslavova E V 2015 The influence of the processes of formation, development and use of human capital on the innovative development of an enterprise *Heteromagnetic microelectronics* **19** pp 118-126
- [19] Kondaurova I A, Kuznetsova A M 2016 Identification of the problems of the formation and use of human capital in the context of innovative development *Drucker Bulletin* **3(11)** pp 108-121
- [20] Noskova K A 2013 The effect of human capital on the innovative development of an organization *Economics and Management of Innovative Technologies* **12(27)** p 10
- [21] Ustinova L N, Ustinov A V, Virtsev M Yu 2015 The study of the influence of elements of intellectual capital on the market capitalization of the enterprise *Economics in industry* **1** pp 88-92
- [22] Dziallas M, Blind K 2018 Innovation indicators throughout the innovation process: An extensive literature analysis *Technovation* vol 80-81 pp 3-29
- [23] Suroso E, Azis Yu 2015 Defining Mainstreams Of Innovation: A Literature Review First International Conference on Economics and Banking (ICEB-15) *Published by Atlantis Press* pp 387-398
- [24] Khmeleva G A 2016 Rating assessment of the level of development of innovative systems of regions *Bulletin of Samara State University of Economics* **9(143)** pp 22-33
- [25] Berezina E V 2019 Formation of a system of indicators for assessing the level of technological development in the sphere of research and development *Innovation and Expertise: scientific works* **1(26)** pp 42-48
- [26] Zharov V S 2018 The use of investment-innovative leverage to assess the directions of technological development of industrial production *Scientific and technical statements of St. Petersburg State Polytechnical University. Economic Sciences* vol 11 **1** pp 177-187 DOI: 10.18721 / JE.11116
- [27] Zharov V S 2018 The relationship of technological and economic development of production systems *Scientific and technical statements of SPbSPU. Economic Sciences* vol 11 **3** pp 32-44 DOI: 10.18721 / JE.11303
- [28] Zharov V S 2018 Investment-innovative analysis of the activity of production systems *Scientific and Technical Journal of St. Petersburg State Polytechnical University. Economic sciences* vol 11 **6** pp 142–152 DOI: 10.18721 / JE.11612