

# Human Capital as an Accelerator with Synergistic Effect of Scientific and Technological Progress

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**Abstract**—The decisive role of human capital in the development of society and the state is undeniable. The degree of change in the qualitative characteristics of human capital under the influence of successive basic technologies is the subject of scientific discussion and depends on the attitude of society towards one or another critical technology and the type of socio-economic system that dominates the territory. Therefore, taking into account the factors associated with its formation under the influence of successive technologies and assessing the contribution of human capital to the economic growth of the state is now increasingly relevant. Moreover, when allocating resources, the problems of human capital development have to compete with other problems, and the qualities of individuals necessary for social development are the subject of discussion by science and society as a whole. The authors developed the concept of the model of “Synergetic cycles”, formed by scientific and technological revolutions, during which the prevailing technologies in the cycle, synergistically interacting with human capital, change. The model is intended for economic assessment of the effectiveness of investing in human capital and has been tested at the level of socio-economic systems of the mesoscale. During the research, special attention was paid to the issues of the current transition to a new synergetic cycle due to the critical increase in the importance of science and innovation for successful social development and geopolitical competition.

**Keywords**—human capital, knowledge capital, key technology, synergy cycle model.

## I. INTRODUCTION

Currently, the most important factor in economic growth is scientific and technological progress, and its main source and driving force is human capital (HC). Innovative and scientific activity, which is based on the process of generating new knowledge from the available knowledge capital, is based on the creative work of individuals and with the synergistic effect of their teams, everything else is only necessary for its implementation. When transferring knowledge capital to production, innovative changes in the region may not achieve the expected results due to the active resistance of the HC in the corresponding type of activity to innovations and, conversely, the creative participation of the collective HC ensures significant acceleration (synergetic effect) of their implementation [1]. The development of a long-term program for the development of the potential of the HC is the most important task aimed at ensuring a strategic competitive advantage for the region. At the same time, the activity of creating a HC for innovative activity at all times was the longest, capital-intensive and technologically indefinite, therefore, highly risky. This explains the moving of the HC,

capable of carrying out innovative activities accompanying the entire process of globalization, into more economically developed territories. Currently, this is manifested in the form of competition for it between countries, regions and firms.

The scientific and technological revolution has radically changed the technological paradigm: there has been a qualitative transition from technologies based on the investment, mainly of energy and material resources, to technologies based on the investment of mainly information capital and knowledge capital, which became in this cycle “non-material factors of production”. In an innovative economy, the basic socio-economic functions of capital have shifted to knowledge capital and information capital, which have become the universal subject, means and product of labor, the main productive force (production requires less direct physical labor and distributes less means of payment). This is due to a combination of trends in mechanization and automation of production processes using infocommunication technologies (ICT).

## II. LITERATURE REVIEW

The concept of “human capital” was introduced by Daniel Bernoulli in [2]. The idea of the HC was disclosed by K. Marx in [3]: “The release of time “for the full development of the individual” can be “considered from the point of view of the direct process of production as the production of constant capital (capital fixe). Permanent capital in this case is a person (capital fixe being man himself).” Until the middle of the 20th century, among economists, the point of view was widespread that the labor market has an unlimited number of manpower, therefore, in case of a shortage of labor resources in one of the sectors of the economy, they can be attracted from others by increasing wage rates.

And only from the 2nd half of the 20th century, a qualitative “leap” began to take place in understanding the role of the HC due to its ever-increasing influence due to the accumulation of its own and borrowed skills, knowledge, and knowledge on the scientific and production processes. As a result, T. Schulz in [4], [5] and G. Becker in [6] set forth the main provisions of the Theory of Human Capital, which is based on an economic approach to human behavior.

## III. RESEARCH METHODOLOGY

The subject of the study is economic relations, emerging in the process of the impact of the HC on the scientific and technological progress of socio-economic systems, the object

of study is the HC of the regions of Russia and Russian enterprises [7].

The study is based on a rational approach combined with structuralist and dialectical approaches to the problem of managing the socio-economic development of territories. The methodological premise of the study is the hypothesis: in the context of a transition to a higher cycle, the role of the HC, especially the intellectual one, increases. For example, in the transition to an innovative economy, in which a significant part of the surplus value is created on the basis of intellectual activity, the corresponding synergetic cycle becomes dominant, and the intellectual HC is the most demanded. The main research method is system analysis.

#### IV. RESULTS

In view of the foregoing, in order to increase the accuracy of predicting the effect of the influence of the HC on the state's economic growth, the authors developed the concept of the model of "Synergetic cycles" formed by scientific and technological revolutions, during which the technologies and energy sources dominating in the cycle, synergistically interacting with the HC are changed [8]. The main provisions of the concept of the model of "Synergetic cycles":

1) the implementation of the achievements of scientific and technological progress is based on the introduction of increasingly efficient technologies for the use of dominant energy sources and is achieved by large investments in the corresponding technologies, science and R&D, which is supported by concomitant advanced investments in education and healthcare, forming the appropriate quality and qualification of the HC. It is this that creates the conditions for the transition to a new cycle and provides quantitative and qualitative foundations for economic growth;

2) the effectiveness of strategic management of the region increasingly depends on investments in the formation of new knowledge, in the creation and implementation of innovations, in the development of human capital and in the innovative management of knowledge capital, intellectual property and human capital [9];

3) the pace and cyclical development of the economy determines the scientific and technological progress, providing:

a) accumulation of qualitative changes in the productive forces of society, leading to a qualitative "leap" (radical transformation) in the latter;

b) changes in the HC: its reproduction in a higher cycle occurs at a new level of information support, knowledge, qualifications, and the education system. It is becoming an increasingly limited resource due to an increase in the volume of investments necessary for its reproduction in the right quality, the uncertainty of training technologies and the characteristics of the human "material" (not everyone is able to work with high technologies and generate innovative ideas);

4) the reproduction of HC cannot be separated from the living conditions of society as a whole (despite some successful attempts), which makes it necessary to consider in a synergetic unity the prevailing energy sources, basic technologies, economic structures and living conditions of society, creating the conditions for the next scientific and

technological revolution. Failure to provide synergistic conditions for the scientific and technological revolution necessary for the development of the region may lead to a geopolitical or even civilizational crisis. Historical science has relevant examples.

Thus, "synergetic cycles" are a set of scientific and technological trends (trajectories) based on a complex of mastered critical technologies that make up the technological basis of the long wave and a qualitative "leap" in development through the main driving force of society (HC) - its productive forces that are characteristic for a certain level of development of an integrated complex of technologically related industries that make up the cycle (macro technologies at a certain stage), based on the common resources of the HC qualifications [10]. All this represents a reproductive circuit, which, as a result of scientific and technological progress, moves from lower to higher, progressive cycles, transforming the HC itself. The complex of the main characteristics of the synergetic cycle is given in Table 1.

The speed of information movement has a special influence on the development of human capital; modern ICTs have removed almost all tangible technical limitations on the speed of turnover and the scale of the turnover of information. The speed of information circulation has always grown practically, and the automation of so far only "routine" operations with knowledge capital is a relatively new phenomenon, the significance of which has not yet been fully appreciated. This phenomenon entails a change in the synergetic cycle, including the emergence of a new quality of human capital and, as a consequence, a revision of management concepts. The current management concept was developed in the last third of the XIX century. On its basis, economic successes were achieved in the late XIX - early XX centuries. Mass (conveyor) production of goods and then services was established. The stock market and the banking sector have become a powerful tool for distributing capital. Socio-economic and socio-political efforts were aimed at ousting numerous small producers from the economy and forming wage workers or semi-finished products producers from them. This was aimed at secondary and, to a large extent, higher education systems. Thus, the issue of revolutionary increase in labor productivity due to mass copying of products and services was solved and the question was raised, if not the complete exclusion of man from the sphere of material production, then a sharp reduction in his role in this sphere. Currently, "uninhabited" production is being created. Thus, human activities will shift to the sphere of work precisely with the capital of knowledge, the production of intangible assets.

TABLE I. THE COMPLEX CHARACTERISTICS OF THE SYNERGISTIC CYCLE. SOURCE: COMPILED BY THE AUTHORS

<i><b>Biosphere Resource Availability</b></i>
Energy sources
Sources of Life Support Products
Sources of raw materials for production
<i><b>Processing and product handling technologies</b></i>
ICT development level
Raw Materials Processing Technologies
Research and Innovation Technologies
<i><b>The quality of human capital</b></i>
Level of intellectual development
Innovative thinking
Values, Loyalty, Honesty
Health
Training technologies

The market of intangible creative results of labor, including the capital of knowledge, has existed almost always. Products circulating on it are alienated only legally; when transferring a material medium, the author does not change; instead of exchanging equivalents, costs are distributed between users, producer and author; they are not consumed during use, do not worsen consumer properties, and, often, can improve them; in the process of use they can only become obsolete (they have no physical wear and tear).

Currently, due to an increase in the share of this market in the total volume of circulating values and ICT as a new technological basis for the circulation process, this market has acquired a new quality and role in the modern economy. The successes of economically developed countries over the past 50 years have been achieved through the production, accumulation and distribution of knowledge capital, including the ability to influence individual and mass consciousness. The traditional "material" factors of production, related to the technological patterns that have lost dominance in economically developed countries, are carried out in other countries.

Nanobiotechnologies are currently being added to existing technologies, and in the future, possibly, cognitive technologies that support all types of activities will be added. Under these conditions, HC of entrepreneurs and specialists capable of creating new knowledge and innovations based on special knowledge, including codified ones, will be able to combine the "material" factors of production in the optimal ratio. Entrepreneurship will not be possible without reliance on fundamental scientific knowledge, which will further enhance the synergistic effect that accelerates scientific and technological progress.

Training will require the transfer to people of knowledge and skills that meet the standards of higher education, which is an investment field, regardless of the commercialization of production relations in this area. The rate of return on financing higher education for employees (investment of the HC) always exceeds the average rate of return for the economy. Of course, this excess depends on the technical and technological level of development of the type of activity (industry), but a qualitative leap in the level of profitability occurs during the transition from traditional to innovative activity. The mathematically synergistic effectiveness of using HC in the region can be expressed as follows.

1. To determine the income from higher education, G. Becker subtracted the earnings of workers who did not continue their education after school from the lifetime earnings of workers who graduated from college [6]. Based on the fact that the rate of return on investment in training is calculated as the ratio of income to costs (tuition, hostel, etc.), he received a value equal to 12-14% of annual profit. Hence it can be assumed that for enterprises (businesses) that produce traditional products (providing traditional services) in the corresponding type of activity, the industry average rate of return for enterprises (business) due to the use of personnel with a higher level of education is determined from the expression:

$$H_{business} \approx (1,12 \div 1,14) \times H_{average} \quad (1)$$

2. For innovatively active enterprises (businesses), the industry average rate of return in the relevant type of activity is  $H_{innact business}$  is defined as:

$$H_{innact business} \approx (10 \div 1000) \times H_{average} \quad (2)$$

The range "10 ÷ 1000" is determined by the temporary monopoly position of enterprises on the innovative products they produce in the market, depending on the share of these products in the total output of the respective enterprise and their demand by the consumer. The forms of profit-taking from innovative activities depend on the state-supported model of social reproduction and the attitude of society towards it, while the model of reproduction is closely related to the quality of human capital necessary to maintain it. This expression can be improved by representing the dependence of the rate of profit of innovation on the average rate of return in the form of a non-linear expression, the values of which during calculations can fluctuate in a given range.

## V. PRACTICAL SIGNIFICANCE

The formation of motivation for scientific and creative activities for the benefit of the state and society is currently taking place, but overcoming the negative experience of the degradation of the Russian system of managing the HC as a result of the revolutionary transformations of the 20th century, in particular, due to the loss of Russia at the end of the 20th century. the position of the holder country and the leading producer of most critical technologies of the currently dominant cycle must be overcome.

Russia's internal crisis problems are superimposed on the global problems of the development crisis of the leading countries, which, according to the authors, are associated with a change in synergetic cycles. There is a change in the management paradigm.

At present, the issue of organizational and economic support for innovation is on the agenda. The management system of the HC in the state and society should ensure the formation of synergistic conditions for the scientific and technological revolution, necessary for the further development of its regions. With the prevailing paradigm of public administration, an increasingly important place in which is the paradigm of ensuring the economic efficiency of all organizational and financial events, the formation of such conditions is possible only if there is scientific and methodological support for evaluating the economic efficiency of measures to form the drivers of scientific and creative activities and the development of human capital..

## VI. SUGGESTIONS AND RESULTS OF IMPLEMENTATIONS

The proposed model was tested at the level of meso- and micro-objects. During testing and practical implementation in solving strategic planning problems, imbalances were identified that jeopardized the achievement of declared strategic goals without significant adjustment of the institutional system operating within the framework of the existing model, the system of economic cycles D.N. Kondratiev. These contradictions are both targeted and resource-based in nature. These models assume mainly the industrial nature of labor, which provides the main surplus value, which required certain qualities of the HC. When developing strategic plans to overcome the current economic crisis, it is advisable to take into account the factor of revolutionary changes in the nature of labor, which brings the main surplus value.

Resolution of these contradictions is possible only at the level of a macrosystem, a large sovereign state or a complex

organization of states with a population of 400 million or more [11]. However, individual mesosystems, large corporations and regions can and do take measures aimed at using synergistic factors to accelerate scientific and technological progress, in particular, innovative development. However, the transition of one mesosystem to a new synergetic cycle without the occurrence of a structural crisis in relation to its macro-system is not possible [12], [13].

This model allows you to create a vision of the quality of the upcoming synergetic cycle and the place in it of a particular mesosystem as a driver that ensures the development of society. Examples of such mesosystems are economic sectors, such as aerospace or ICT, as well as clusters of priority development areas..

## VII. DISCUSSION

The described model needs clarifying the coefficient reflecting the non-linearity factor of the growth rate of return on the contribution of the HC to innovation. If G. Becker's approach [6] is based on the dynamics of workers' incomes and expenses, and the described model assumes a proportional growth of the employee's income and his labor productivity, which is close to linear, then factors such as market of capital and knowledge limitation counteract the non-linear growth of the rate of return on the contribution of the HC to innovative activities, as well as competition in this market.

An important factor is also the institutional constraints on the growth of profitability of individual projects and a set of innovative risks that level the profitability of innovation in general. The market of fundamental scientific knowledge has not yet developed, since the bulk of the capital of fundamental knowledge is produced at the expense of public resources and is considered the property of society. When modeling the quality of mesosystems that are supposed to be used as a driver for the transition to a new synergetic cycle, it is necessary to take into account the factors of socio-economic security of a large system

Another factor that should be taken into account in the future when modeling the synergistic influence of HC on scientific and technological progress and, conversely, is the development of cognitive technologies. It is difficult to say whether these technologies will be included in the base of the 6th technological order or will they develop on the periphery of other critical technologies in order to take a leading place among the basic technologies of the 7th technological order in the next round of the long wave of the economic cycle. But at the same time, cognitive technologies will significantly change the requirements for the HC and its place in the system of social reproduction, changing the very nature of the synergetics of social production and scientific and technological progress, which will lead to a new synergetic cycle.

## VIII. CONCLUSIONS

1. The proposed concept of "Synergetic cycles" consists in the synergistic effect of the action of the corresponding energy source and related technologies on the human capital, especially the intellectual one, in particular, the conditions for its reproduction. This approach will allow, according to the authors, to improve the quality of forecasting the development of the territory management system to the level necessary for transition to higher synergetic cycles through

the planned implementation of scientific and technological revolutions aimed at replacing the prevailing energy sources and related technologies and the quality of reproducible HC. This is urgently needed when investing in investment horizons that exceed the capabilities of statistical forecasting under the condition of continuous changes in the quality of the HC and the methods and conditions for its reproduction in the territories. In particular, the convergence of ICT and nanobiotechnology with the cognitive technologies of human capital will be the next step in enhancing the positive synergistic effect, accelerating scientific and technological progress. Each new cycle is accompanied by a change in the qualification structure of the HC. The convergence of ICT, nanobio- and cognitive technologies is oriented and provides, above all, purely cognitive processes. For example, in nanobiotechnologies, work is carried out with very subtle matters, the perception of an object (process) occurs through, among other things, special language figurative models so that researchers can work with objects of the microworld, for which it is necessary to create appropriate visualization languages, representations. That is, it is a cognitive method of scientific knowledge, which assumes new rationality and vision, as well as a completely new idea of the place of the HC in the world and the methods of its preparation.

2. Currently, the main trend in the world that determines the vector of the development of the HC with the greatest degree of probability is that the future humanity is suffering a crisis in organizing its life forms, which as a rule causes financial, economic and other types of crises, as a result of which humanity will be actively searching new forms of its organization and ways of using the HC, especially the intellectual one.

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