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A Comprehensive Framework for Improving the Assessment of Human Capital Quality: Evidence from Regional Analysis in Western Kazakhstan

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ABSTRACT: This study addresses the growing need for more robust and systematic approaches to assessing the quality of human capital in the context of ongoing socio-economic transformation. Human capital is recognized as a key driver of sustainable economic growth, regional competitiveness, and improved development outcomes. Its quality is shaped by institutional environments, state social and educational policies, and investment levels in education, healthcare, and professional skill development. The main objective of this study is to enhance existing approaches to evaluating human capital quality through an integrated analytical framework. The methodology combines a systematic literature review, comparative analysis, and conceptual modeling to capture the multidimensional nature of human capital as an economic, institutional, and social construct. This interdisciplinary approach enables a more comprehensive understanding of how human capital quality can be measured and interpreted across regions. The originality of the study lies in its synthesis and classification of existing measurement approaches, with particular attention to the context of Kazakhstan's socially oriented economic model and sustainable development priorities. The research proposes a structured framework for ranking human capital quality into high, medium, and low levels based on key assessment criteria. This classification provides a practical tool for policymakers to evaluate regional disparities and improve the design of socio-economic development strategies. The findings contribute to both theoretical advancement and practical policymaking by offering an improved basis for monitoring, comparing, and enhancing human capital quality at the regional level.

Keywords: Human capital, Quality assessment, Regional development, Investment, Socio-economic policy.

I. INTRODUCTION

Based on the growing interest in the development of the human capital of the nation, on the part of an increasing circle of stakeholders, in 2025 budget expenditures on the social sphere (including education, healthcare and services to people) amounted to about 9.6 trillion tenge, which indicates a high state rate on its development [1], which actualized the need to improve approaches to assess human resources management and develop programmatic measures to increase it, for the sustainable development of the economy and society as a whole, in the light of which measurement becomes a key task from the point of view of developing and

implementing effective human resource management policies [2]. These changes were prompted by the fact that Kazakhstan ranked 68th in the Human Capital and Research component, which is relatively high among countries with a similar income level [3].

It should be noted that the ambiguous interpretation of the concept of human capital also leads to a variety of approaches to its quantitative measurement and evaluation. At the same time, we can agree with the opinion of some experts that significant differences in approaches to measuring human capital can be determined depending on the level of their consideration, since the tasks of measuring the human capital of an individual, organization (enterprise) and/or region as a whole, and require the use of fundamentally different methods and different indicators, assuming forced differentiation of research tasks and construction of specific mechanisms and measurement tools [4]. This study makes three main contributions. First, theoretically, it develops the concept of human capital quality as a multidimensional construct integrating education, health, and social development factors. Second, methodologically, it proposes an integrated system of economic and mathematical models for assessing human capital quality. Third, empirically, it provides evidence from the regions of Western Kazakhstan, demonstrating the relationship between human capital quality, innovation activity, and regional economic performance.

II. RELATED WORK

For conceptual clarity, it is important to distinguish between several related categories. Human capital refers to the stock of knowledge, skills, and abilities embodied in individuals. Human potential reflects latent capabilities that may not yet be realized economically. Human development is a broader concept encompassing well-being, education, and health. In this study, human capital quality is understood as the effectiveness of human capital in generating productivity and innovation outcomes. In contrast, human capital quality in this study is defined as the effectiveness of human capital in generating productivity and innovation outcomes, emphasizing not only the quantity of resources but also their functional efficiency. In recent years, human capital assessment has become an important area of research in economics and social development. Traditional methods, such as the World Bank Group's Human Capital Index, mainly rely on quantitative indicators such as investment in education and health and employment rates. However, such indicators do not always reflect the quality of human capital at the regional level, so it is necessary to develop approaches that include comprehensive analysis methods that consider both quantitative and qualitative characteristics of the labor force in different regions of the country. Since improving methods for assessing the quality of human capital is important for an accurate analysis of regional characteristics and the formation of an effective policy in the field of human resources [3, 4]. In this context, human capital quality is defined as a multidimensional construct, combining educational outcomes, health status, and social development conditions. Unlike traditional indices such as the Human Development Index, this approach emphasizes productivity, adaptability, and innovation capacity rather than general welfare indicators. Unlike traditional indices such as the Human Development Index, which primarily reflect general welfare, this approach focuses on the productive and innovation-oriented capacity of human capital.

According to [5], when assessing human capital, the focus is on economic returns, having high incomes and economic growth rates. At the same time, it is necessary to realize that investments in the potential of human resources also bring non - economic benefits, namely, improving the health of the population, better education, expanding the scale of social programs, and other important benefits of socialization of economic development. Moreover, in contrast to the fixed capital, which is worn out in the process of use, human capital accumulates in the form of competence potential, and increasingly manifests itself as a long-term and, at the same time, stable factor of economic development. In general, the analysis of approaches to the methods of assessing human capital allows us to identify the following classification criteria: At the management level: at the micro level, the assessment of personal capital is carried out both for individuals, which together allow you to get an integrated assessment of the organization's human capital, and for the organization, at the corporate level enterprises and regions, at the macro level on the scale of the national economy.

In practice, the main method of macro-level assessment of human capital is the calculation of the human development index a (HDI) as an integrator of indicators that reflect in a generalized form such factors as the state of the population's standard of living, health, degree of education, and others. It is worth noting that international experts, when considering human capital as a set of accumulated knowledge, skills and abilities, distinguish educational skills and socialization skills in its structure, in accordance with which various approaches to assessing human capital are manifested: for example, the approaches used in the United States are aimed at assessing the presence and degree of development of skills in socialization, and in the countries of South-East Asia, there is an emphasis on testing knowledge and the ability to acquire new skills, etc. According to the approaches used: within certain limits of target installations, either the cost, income, or depreciation assessment methods are taken as the basis [6]. Thus, experts believe that the cost approach is comparable to the process of continuous inventory of fixed capital, that is, the reserves of human resource potential are estimated in the form of accumulation of the cost of all costs that are brought to its formation, and which can be considered as investments in human capital.

This approach is relatively easy to apply if data on public and private expenditures on formal education, as well as on expenditures on out-of-school training, are complete. At the same time, this approach does not allow us to fully consider all the features of the educational process of a particular person, as well as the manifestations of human potential and the quality of future human capital determined by employees (specialists) with a higher level of professionalism. This approach was most widely used in the United States and covered the costs associated with raising children, education, and other purposes that are relevant to the formation of educational values, as well as the cost of student time, considering the possible earnings that were lost by students during their studies.

An approach to measuring the quality of personal income based on the income method calculates it as the present value of expected labor income in the future, which can be obtained during the life of people currently living, considering a wide range of factors of influence demographic, educational, labor, and many others related to the standard of living of the population. This approach makes it possible to compare relatively the degrees of importance of these factors and to draw the necessary conclusions for conducting a rational management policy based on the analysis of the calculated estimates. This scientific and methodological approach to accounting for all incomes throughout life is accepted by the expert community as the most promising for the purposes of including human capital in the System of National Accounts in the future [5]. The World Bank's specialists developed a discount method for quantifying the value of human capital, which boils down to the fact that initially, at a certain rate of return on the total national wealth, the value of the latter is calculated, and then the value estimates of land, forest and water resources, fixed assets, mineral reserves, and other assets are deducted from the resulting amount. As a result, there remains a cost estimate of the potential of human resources, which can be implemented as human capital.

Study [6] summarizes that the whole variety of methodological approaches to assessing human capital is reduced to several basic ones, the main ones being both costly and profitable. At the same time, according to this expert, the cost method is based on the integration of total expenditures for education, professional training and retraining of specialists, and other costs of society, which are traditionally classified as investments in the formation of high-quality human potential. The value of human capital itself is defined as the sum of accumulated net investment in the development of an individual, carried out at all stages of its life cycle.

The income approach is based on an assessment of the employee's income, which can be considered in the form of a return on investment in educational and qualification processes. The use of this approach in assessing human potential implies, first, the use of a mechanism and tools for capitalizing income that can be obtained from the realization of human potential as a factor of additional capital in production. It is according to this scheme that the processes of accumulation, formation and use of the current employee's human capital are carried out throughout his economic activity. This expert believes that both methodological approaches are not entirely correct, since they do not consider the quality of human capital, and therefore, along with the methods that make it possible to assess the cost of human capital, there is also a method for assessing its quality, which can be classified as an expert approach.

The essence of the expert approach is that qualitative indicators that characterize both the individual characteristics of a particular employee and the properties of the company's employees in aggregate are directly evaluated. Thus, according to [6], the expert method, as a method of qualitative assessment, can be considered an important link in the system of methods for assessing human potential and, accordingly, human capital, since it most objectively evaluates the qualitative components of human resources [6]. Currently, there is no difference of opinion in the scientific community that investing in the development of the competitive potential of human resources in each individual state is appropriate and economically justified, moreover, countries should cooperate on the exchange of experience and strategies for the development of human capital, considering its cross-country cumulative effect. However, it is necessary to keep in mind such a problem as the uneven nature of the formation of human potential within countries with vast territories [7].

In particular, the latter is relevant for Kazakhstan, with its uneven socio-economic development of the regions. In principle, do not express doubts about the main approaches discussed above, based on the processes of investing in human resources, but emphasize that it is necessary to consider the existing shortcomings. In their opinion, researchers determine the value of human capital, while ignoring the factor of demand for high-quality labor resources. The method of assessing the quality of human capital, based on the income received from its use, is based on the calculation of the annual wage fund, defined as the difference between national income and property income [8]. However, experts over time came to a consensus that in real life, income indicators and labor productivity do not always have equally directed development trends, and if income (earnings) changes for any other reasons other than changes in labor productivity, then the results obtained using this method will also be like those of the previous generation. not entirely objective in nature. Thus, the method of assessing human capital by labor productivity cannot be considered the best universal way to solve the problem of assessing personal income in individual countries and in different time periods.

According to Kazakhstani experts [8], the more modern method, which was formed later than others, built on measuring human capital using indices, is best suited for cross-country and cross-category comparisons for ranking human capital resources for different countries, regions, and social groups. In general, out of a fairly large number of approaches and indicators used to measure human capital at different levels of its formation and use, not all of them can be applied in management practice for various reasons and their specific features, especially considering the state of the information and analytical base. Moreover, their diversity creates a situation where the estimates obtained on their basis are weakly correlated with each other, which significantly complicates cross-country comparisons, which, however, are necessary to assess differences in the provision of this resource to national economies [8]. These theoretical constructs are translated by some researchers into mathematical formalizations that have greater applied value for management practice. Thus, to assess the magnitude of human capital:

$$HK_k = \sum_{t=1}^{n}(S - Z)(1 + i)^{-t} \quad (1)$$

Where HK_k denotes an individual's human capital at age k; S represents the individual's income; Z refers to wages from unskilled labor plus investment costs; n is the age at which active working life ends; and i is the rate of return on human capital.

Another formalized approach to assessing human capital involves examining the extent to which investments in human capital influence the growth of macroeconomic indicators such as *GDP* or national income. For this purpose, factor-type mathematical models are employed and used the following formula to assess the impact of investments in human capital on the growth rate of national income:

$$ND = k \cdot MPK + TPL \cdot IL \quad (2)$$

Where *ND* denotes the growth rate of national income; k is the capital intensity coefficient; *MPK* represents the marginal productivity of capital; *TPL* is the growth rate of the labor force; and *IL* is the share of labor in national income. There are also formalizations of the relationship between production and the human capital factor, which can be attributed to studies evaluating the effectiveness of the human capital concept through its impact on production growth rates and, consequently, on output volumes (goods and services). In this regard,

Study [1] refers to a previously developed production function used to calculate an employee's wage as a mathematical relationship between wages, the level of education, and other factors:

$$ln\,Y = \beta_0 + \beta_S S + \beta_1 EXP + \beta_2 EXP^2 + \alpha \quad (3)$$

Where Y denotes employee wages; S is the duration of schooling; EXP represents work experience (labor skills); and α is the random component [1].

Study [9] proposes a model-based formalization in the form of a production function, in which the dependence of output volume on the classical factors of capital and labor is supplemented by the human capital factor grounded in knowledge:

$$Y = AK^{\alpha}L^{\beta}e^{\gamma+\phi+\delta+\varepsilon} \quad (4)$$

Where (Y) denotes the output of goods (services); (A) is an integral constant dependent on the initial conditions of factor endowment; (K) represents physical capital; (L) is the classical form of labor input; and (e) is the base of exponential growth characterizing the economic significance of knowledge, innovation, and organizational impacts. (\alpha) and (\beta) are the elasticity coefficients with respect to capital and labor, respectively; (\gamma) is the parameter determining the contribution of innovation to output growth rates; (\delta) assesses the contribution of the human capital factor to output growth rates; and characterizes the contribution of organizational factors to output growth rates [11].

As noted above, all these theoretical and practical research findings, including those related to formalization, are primarily concentrated at the micro-level, with a very limited scope of studies at the macro-level and an even narrower focus at the meso-level. It is this latter circumstance, in our view, that determines the relevance of the present study for the regions of Western Kazakhstan. Such a situation with a differentiated state of research is determined, in our opinion, by the fact that there are still urgent tasks in terms of improving the key aspects of information and statistical support for the processes of quantitative assessment of the concept of human capital. Along with this, the lack of a generally accepted theoretical and methodological approach to measuring the effectiveness of human capital can also be attributed to the category of unresolved issues. The exceptional importance of this task, according to [9], stems from the need to use data on the reserves of human potential and the level of human capital development in the conditions of:

- planning to improve the quality of human capital in the current trends of population aging.
- accounting for the human capital's contribution to socio-economic and technological development.
- assessment of human capital as an intangible element of national wealth.
- development of measures in the field of forming the competitive potential of human resources, developing human capital on this basis, and increasing its efficiency in the application to production.
- Human capital needs other approaches that determine the relationship between quality and efficiency through the final impact of the quality of human capital on the socio-economic development of the country, regions and other socio-economic systems, which implies a comprehensive, systematic approach using economic and mathematical models.

According to [10], the existing methodological approaches to assessing the effectiveness of investments in human potential remain limited and do not provide sufficient depth of analytical research. If the conditions of completeness of accounting for factors, investment levels, can more objective assessments of the real contribution of the quality of personal property to economic growth be identified [10]. Human capital represents the human potential in its real expression in conjunction with the socio-economic conditions of its formation, development, and use. There is no doubt that the realization of human potential in the form of a human capital factor at all levels of the managerial hierarchy requires the presence of appropriate prerequisites the motivation of people to fully use their accumulated human potential [8].

Assessing human capital quality is becoming more important than simply counting how many years' people spend in school or how many degrees they hold. The main weakness of older approaches is that they often treat education as a quantity variable, while real productivity depends on what people can do how well they can read, solve problems, adapt to technology, and stay healthy enough to work effectively. Recent measurement work pushes the field toward outcome-based assessment, where education and health are treated

as capabilities that shape lifetime productivity rather than just service inputs [11]. This shift matters because human capital losses are not only about school access; they also come from learning interruptions, weak skill formation, and unequal opportunities to use skills in real jobs, patterns widely documented in recent global human development analysis [15]. In this sense, better measurement is not a technical detail it changes what governments prioritize and how they judge progress.

A practical example of this change is the Human Capital Index, which frames human capital quality as the combined effect of health and learning on future worker productivity [11]. Instead of saying people studied 12 years, it asks what share of full potential a child born today is likely to reach, considering survival, the absence of stunting, and high-quality schooling. This kind of index pushes measurement away from inputs (how much education was provided) toward outcomes (what learning, and health were achieved) [12]. More importantly, newer extensions of this framework highlight that measuring skills is still incomplete if people cannot use them in the labor market; utilization-adjusted human capital indicators therefore account for unemployment and underemployment when interpreting human capital scores [11]. That adjustment connects quality measurement directly with labor-market reality rather than education statistics alone. However, even strong index approaches can be improved. One major direction is to connect schooling more directly to measured skills instead of duration alone. The gap between years of schooling and learning achieved differs widely across countries, which is why newer macroeconomic measures build human capital indicators by combining schooling quantity with international student and adult skills assessments. Instead of assigning arbitrary weights, these models estimate how strongly adult skills relate to earlier student performance and schooling levels across cohorts. A central empirical result is that the elasticity of human capital with respect to education quality can be several times larger than with respect to schooling quantity, meaning that test-measured learning gains matter more for long-run productivity than additional schooling years alone [13]. Because student learning enters the workforce gradually, these models also emphasize time lags between education reform and productivity outcomes.

Another improvement is to move from purely national averages to sector and industry-level measurement since productivity depends on where skills are located and used. Industry-level quality-adjusted human capital measures combine schooling data with education-quality indicators and employment composition by cohort to estimate workforce capability at sector level. This approach was developed precisely because traditional proxies like attainment shares often fail to show a stable relationship with productivity growth. When quality adjustment is introduced, the statistical link with industry productivity becomes clearer, especially in goods-producing and technology-intensive sectors [14]. In practical terms, this means assessment should not rely on one national average but examine how human capital quality is distributed across industries.

A third direction is to treat human capital quality as something formed across the whole life cycle through education, health, continuous training, and innovation exposure not only through formal schooling. Recent applied research on economic assessment of human capital quality stresses interconnected pillars such as access to effective education, lifelong learning systems, workforce health, digital competence, and innovation capacity. These studies show that firms and economies that invest in digital skills and continuous training adapt more successfully to technological change and use capital more efficiently [16]. From a measurement viewpoint, this implies that quality indicators should include adult learning and skill renewal, not only initial qualifications. Methodological discussions of human capital assessment also distinguish cost-based, income-based, and indicator-based approaches, and recommend combining them rather than relying on a single method [12].

There is also a strong argument for integrating human-capital quality measurement with broader human development tracking. Global human development reporting shows that crises can create long-term learning and health setbacks that affect future workforce quality, not just current income levels. School closures and disrupted health services reduce learning and capability formation at critical stages, and recovery is often unequal across countries and social groups [15]. Because of this, quality assessment should include resilience and recovery dimensions, not only static levels. This also depends on having reliable and comparable education and learning data systems, since weak statistical coverage can distort quality comparisons and trend analysis [19].

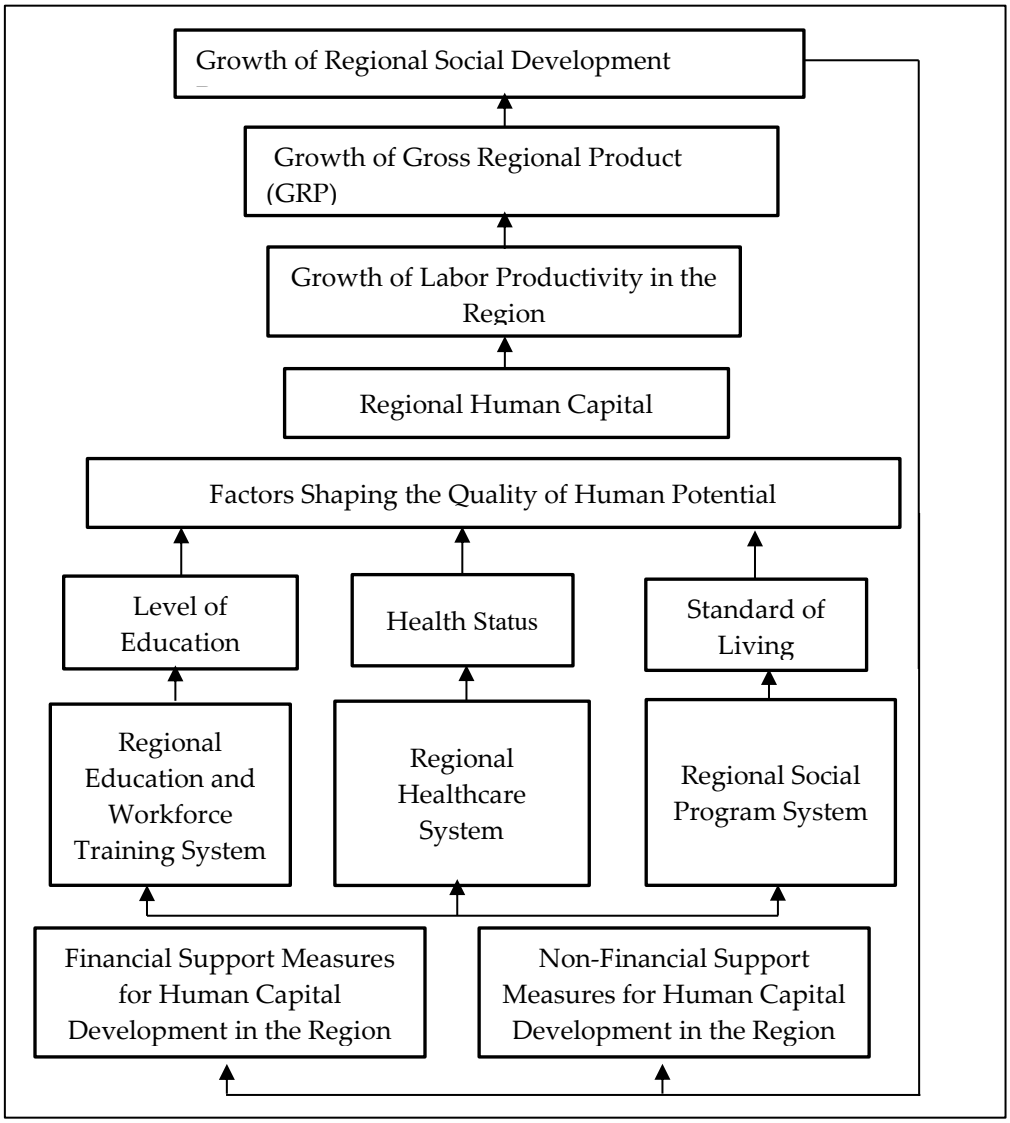


FIGURE 1. Scheme of the process control mechanism formation of state of emergency and its implementation in the form of human capital at the meso-level of management.
Note: developed by the authors of the study.

The proposed conceptual framework assumes that human capital quality affects innovation activity through enhanced skills, knowledge accumulation, and increased labor productivity. Innovation activity, in turn, contributes to regional economic performance, forming a dynamic and mutually reinforcing relationship between human capital development and economic growth. In accordance with this organizational scheme, it is advisable to form a system of predictive and analytical justifications for the development of the concept of human capital based on the construction of a set of economic and mathematical models. In our opinion, it is advisable to form the desired model complex at 3 levels, considering different levels of managerial significance of regional development indicators (Figure 2).

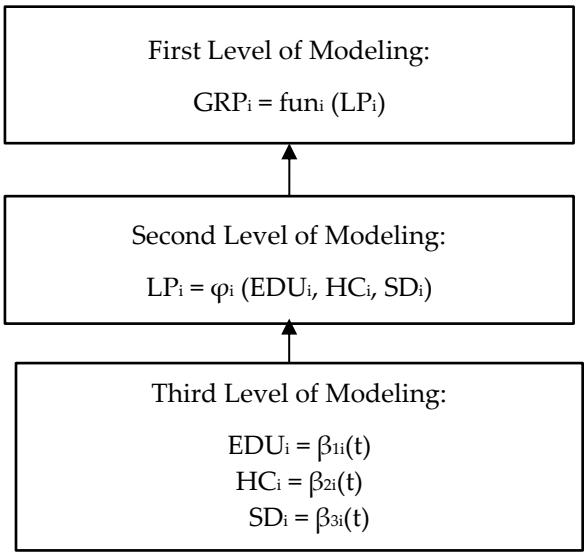


FIGURE 2. Scheme of organization of the complex of models of the I-th region.
Note: developed by the authors of the study

Where *GRPi* denotes the Gross Regional Product of the *i-th* region; *LPi* is labor productivity in the economy of the *i-th* region; *EDUi* represents expenditures on education and workforce training in the *i-th* region; *HCi* refers to healthcare expenditures in the *i-th* region; *SDi* is expenditures on social development in the *i-th* region; and, ϕi, and βij represent functional dependencies. In addition, for each region of Western Kazakhstan, it is possible to assess the volume of the multiplicative effect in terms of the increase in production of goods and services in economic sectors associated with the processes of human potential formation, based on the region's education, healthcare, and social sectors. At the same time, related sectors may be located outside the region under consideration, taking into account interregional linkages. The calculation formula for the multiplicative effect can be represented as follows:

$$\Delta GRP_{cum,i} = A \cdot \Delta GRP_i \quad (5)$$

Where $\Delta GRPcum, i$ denotes the cumulative effect in terms of the increase in Gross Regional Product of the *i-th* region; $\Delta GRPi$ represents the direct effect in terms of the increase in Gross Regional Product of the *i-th* region; and A is the sum of the full material cost coefficients across all sectors related to education, healthcare, and social development in the intersectoral input–output matrix of production and distribution.

In particular, the parameter A is defined as the sum of the full material cost coefficients across three key sectoral directions:

$$A = \sum_j a_{1j} + \sum_j a_{2j} + \sum_j a_{3j} \quad (6)$$

Where a_{1j} denotes the full material cost coefficient of the education sector for the *j-th* related sector; a_{2j} represents the full material cost coefficient of the healthcare sector for the *j-th* related sector; and a_{3j} is the full material cost coefficient of the social sector for the *j-th* related sector.

The total economic effect can be assessed as the sum of the direct economic effect and the cumulative effect:

$$\Delta GRP_{cum,i} = A \cdot \Delta GRP_i \quad (7)$$

Where ΔGRP_i, total is total economic effect determined by the development of human capital in the *i-th* region.

In contrast to the cumulative effect, which is defined as an additional effect from the development of related industries, both in the region of consideration and outside it, the synergistic effect is associated with the processes of ensuring the growth of the competitive advantages of a sub-region based on the integration of joint development efforts of a group of regions that make up the sub-region, Figure 3).

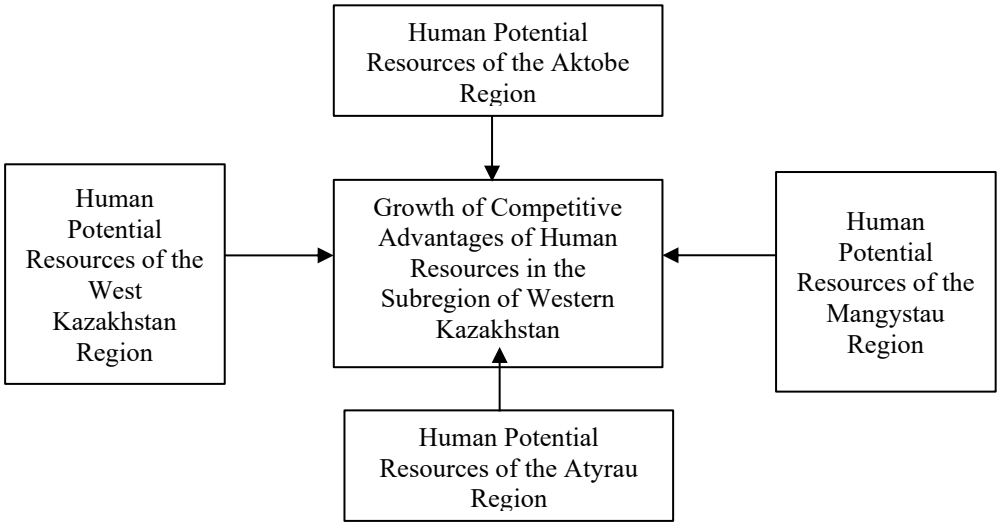


FIGURE 3. Scheme of forming a synergistic effect human capacity building processes.
Note: developed by the authors of the study.

We can fully agree with [21] opinion that against the background of a number of theoretical issues of the development of the concept of human capital, scientific and methodological support for its quantitative assessment, no less relevant issues of measuring the quality of human capital in the context of its impact on economic growth have practically fallen out of the researchers ' field of view [21]. At the same time, there is an understanding of the fact that it is the quality of human capital that is important for any national economy, since it is increasingly becoming one of the most important factors of economic growth. Study [22] emphasizes that it is possible to adopt advanced innovative technologies from more economically developed countries, but still not fully use them. it will work if there are no relevant knowledge and qualifications among the personnel called upon to use these technologies [22].

In terms of implementing the principle of moving from quantity to quality, we can note a paradigm shift by the World Bank: if earlier it encouraged and implemented investments in economic development to solve problems with poverty on this basis, then starting in 2018 the World Bank changed the emphasis in its investment policy. Today, this international financial institution uses an investment approach to mobilize investment directly in people. For this purpose, the World Bank Group specialists developed a new HDI, which makes it possible to assess the human contribution to ensuring the productivity of the next generation of labor resources. In general, this index, unlike the used Human Development index (HDI), The HDI and other indices, is more focused on assessing the quality of human resources in terms of their adequacy to the urgent goals and objectives of economic development.

At the same time, experts express the opinion that the characteristics of the quality of human capital that can be used for management purposes may differ in the regional cross-section, depending on the current conditions and priority sectors of the economy, and even on the management decisions made. In other words, the problems in this area are rather related not so much to the development of universal indicators of the quality of human resources for countries and regions, but rather to the development of methodological approaches to solving problems of identifying significant and key characteristics of human resources and quantifying them

for specific regions in specific conditions for planning and monitoring the results of specific management actions [23].

World bank Group experts believe that the scientific community is aware of the many benefits of improving the quality of human capital, but this knowledge has not yet formed the basis for convincing governments of developing countries to take real actions to invest in the quality of the concept of private equity. And one of the significant obstacles is the lack of more convincing data that would demonstrate the full benefits of investing in human capital, not only for health and education managers, but also for heads of state and influential officials around the world. That is why, according to experts of the World bank Group, the human capital index introduced for different countries of the world can stimulate the growth of public spending in the development of people, with the expected effective return on the growth of the quality of private property [24].

In general, the analysis of the research base shows that, on the one hand, there is an extreme narrowness of research on measuring the quality of human capital, and on the other hand, individual studies that take place led to the understanding that the search is possible mainly in the form of various combinations of the main factors that determine the processes of forming the potential of human resources.

In this context, reference can be made to [25], who proposes calculating the Human Capital Quality Development Index (HCQDI) of a region as the sum of educational, medical-sports, and cultural indices:

$$HCQDI_i = 1.5EI_i + MS_i + CUL_i \quad (8)$$

Where $HCQDI_i$denotes the Human Capital Quality Development Index for the *i-th* region; $EI_i$is the Educational Index of the *i-th* region; MS_irepresents the Medical-Sports Index of the *i-th* region; and $CUL_i$is the Cultural Index of the *i-th* region.

The proposed model (9) is a composite index of the development of the quality of human capital in the region, formed as a weighted sum of three key components: educational ($IOBR_i$), medical and sports (MS_i) and cultural (K_i). The increasing coefficient of 1.5 in the educational index reflects the priority of education as a basic factor in the formation of competencies and labor productivity, which determines the region's ability to innovate and adapt. The *IOBR* indexes MS_i and K_i indices are pre-normalized to a single scale, which ensures comparability of components and correctness of aggregation.

For the educational index, this expert set an increasing coefficient equal to 1.5, which is due to the general recognition of experts in the field of research on the theoretical foundations of human capital of the key role of education, since it is the education system that reflects the process of forming knowledge and skills that are later used in the process of work [27]. Fixing the increasing coefficient at this level is conditional, since, in our opinion, the value of such a coefficient can and should be differentiated by region, depending on the ratio of the levels of development of the education system and the economy. The development of human capital in national economies is uneven, with the manifestation of the so-called Matthew effect at the regional level, namely:

- higher rates of development and use of human capital are observed in regions with higher levels of socio-economic and innovative development, with a predominance of large agglomerations and a concentration of investment and other means of development. These regions also show faster, and higher-quality growth based on the use of technologies of the 6th mode.
- in the same regions that show a lower, and often lower level of socio-economic and innovative development, we can observe a trend of consistent, steady depletion of human capital, which can be explained by the lack of centers of attraction of capital, the relocation of high-tech industries to other, more developed regions where high-tech technologies are widely used.

It seems that the conclusion of these experts on the necessary measures to influence the processes of formation and implementation of human capital is also extremely important. In their opinion, to strengthen the technological complexity of the economy, establish spatial and digital symmetry, it is necessary to apply several measures to level the situation and more evenly and efficiently form and use human capital, and most importantly, in our opinion, eliminate the fragmentation of strategic planning at the regional level. Such an understanding of the objective nature of the differentiation of quantitative and qualitative indicators of human capital is very relevant for the regions of Kazakhstan, especially in the Western region. In this regard, we

consider it not only possible, but also most appropriate to apply the above methodological approach on the basis of a formalized model (9). Based on the understanding of its excessive simplification, we consider it necessary to significantly develop the model tools themselves, using economic and mathematical models in their interrelation at different levels of formation and application of traditional factors-education, health and social development.

According to our methodology of a set of economic and mathematical models for assessing the quality of human capital, it is advisable to link to the research chain "total average per capita expenditures on the evelopment of factors of human resource potential formation *JZ* →human capital index *JHC* →level of innovation activity in the economy "Jact", the organizational scheme of which is shown in Figure 4.

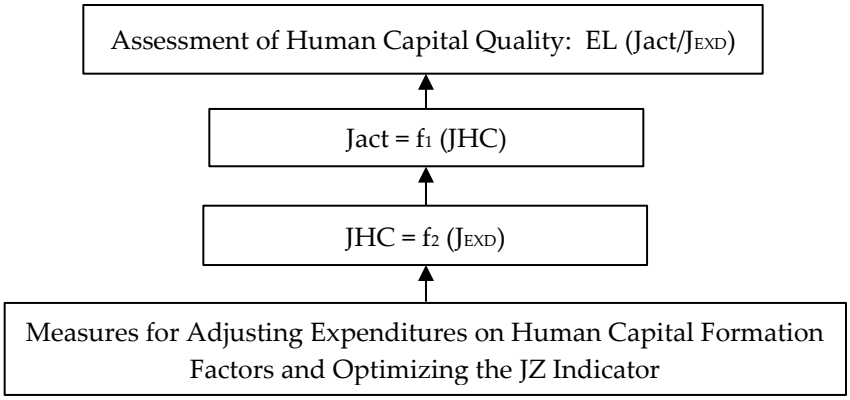


FIGURE 4. The scheme of estimated calculations of the quality of personal data.
Note: compiled by the authors of the study.

Formula for Calculating the JEXD Indicator:

$$JEXD = \frac{EXD_1+EXD_2+EXD_3}{N} \quad (9)$$

Where EXD_1 denotes expenditures on the development of the education system; EXD_2 represents expenditures on the development of the healthcare system; EXD_3 is expenditures on social development; and N is the total population. Thus, while the Human Capital Index (*HCI*), calculated according to the World Bank Group methodology, reflects the quantitative dimension of human capital by assessing the efficiency of expenditures on human potential formation processes, the measurement of the level of innovative activity in the economy attributable to human capital captures the qualitative dimension of human capital, indicating its influence on the competitiveness growth of the national economy as a whole and its regions. The latter can be quantified using the elasticity indicator $EL(J_{act}/J_z)$, which reflects the responsiveness of the innovative activity index to the per capita expenditure index on human capital formation, calculated as follows:

$$EL\left(\frac{J_{act}}{JEXD}\right) = EL_{1\left(\frac{J_{act}}{JHC}\right)} \times EL_{2\left(\frac{JHC}{JZ}\right)} \quad (10)$$

Where *EL1* denotes the elasticity of innovative activity with respect to human capital, and *EL2* represents the elasticity of human capital with respect to per capita expenditures on human capital development.

III. MATERIAL AND METHOD

In this section, we would like to point out that, because of the previous assessment models and to improve the assessment methods of human capital, we have chosen a methodology that is determined by the interdisciplinary nature of human capital, considered as an economic, institutional, and social category [28, 29]. Therefore, to apply the presented research methods, the study itself was divided into several stages. This

approach is also consistent with Endogenous Growth Theory, which emphasizes the role of human capital and innovation as key drivers of long-term economic growth.

The first stage was a systematic literature review aimed at identifying existing theoretical and methodological approaches to assessing human capital. The methodological basis of the review is the principles of structured analysis of scientific sources used in modern economic research. The selection of publications was carried out according to the criteria of relevance to the topic of human capital assessment, methodological significance, and scientific citation. The use of international academic databases ensured that the sample was representative and reduced the risk of methodological bias. During systematic analysis, it is revealed that the existing models for assessing human capital can be divided into index approaches, econometric models, and multi-factor composite indicator systems [13]. To ensure the correctness of the econometric model, several diagnostic and specification tests were performed. Multicollinearity was evaluated using VIF statistics, heteroskedasticity was tested using the Breusch–Pagan test, and panel tests for unit roots confirmed the stationarity of variables. The choice between models of fixed and random effects was made based on the Hausman test. Stability analyses with alternative model specifications confirmed the stability of the results obtained. Index models are focused on aggregated macroeconomic indicators and are widely used in international comparative studies. Econometric methods focus on quantifying the contribution of human capital to economic. Composite indicators consider complex characteristics of human potential, including education, health, and the institutional environment [17].

The second stage of the study was comparative methodological analysis, aimed at identifying the limitations of existing approaches. The analysis was carried out according to the criteria of completeness of measurement, sensitivity to institutional changes and the ability to consider the qualitative parameters of human capital. The results of the analysis confirmed the conclusions that most existing models are mainly focused on quantitative macro indicators and do not sufficiently reflect the dynamic characteristics of human potential, such as innovation, adaptability, and learning ability. The third stage of the study was conceptual modeling, aimed at developing an improved framework for assessing the quality of human capital. The theoretical basis is the methodology of composite indices and multi-criteria evaluation framework, which allows integrating quantitative and qualitative indicators into a single analytical model [17]. The proposed conceptual framework is based on a multi-level approach that includes educational, social, institutional, and innovative components of human capital.

The methodological novelty of the study is the transition from a static assessment to a dynamic model of human capital analysis. Unlike traditional approaches, the proposed model considers the ability of human resources to learn, innovate, and adapt institutionally. This approach is consistent with modern theories of endogenous growth, which consider human capital as a key factor in long-term development [18].

The integration of systematic review, comparative analysis, and conceptual modeling forms a comprehensive methodological research platform. The proposed framework can be adapted to different national contexts and used in strategic human development planning. Thus, the research methodology ensures the scientific validity and practical applicability of the results. Thus, the applied methodology provides an applied focus of research and is focused on the formation of an instrumental basis for assessing the quality of human capital in the system of state and regional management. The integration of systematic review, comparative analysis, and conceptual modeling makes it possible to transform theoretical approaches into a practice-oriented analytical framework suitable for monitoring socio-economic processes and making managerial decisions. The proposed methodological approach ensures comparability of indicators, adaptability to regional specifics and the possibility of using the results in strategic planning, which increases the applied value of research and creates the basis for subsequent empirical developments in the field of evaluating the effectiveness of investments in human capital.

To conduct specific predictive and analytical studies based on the implementation of the scheme proposed by us, auxiliary tables of necessary data were compiled in the context of the regions of Western Kazakhstan (Table 1), which used data on the human development index (*HDI*), the values of which take place in the regions of Kazakhstan. We used the formula for the relationship between the indices of human development and human capital, derived by experts for the group of developing countries, which includes Kazakhstan [26]:

$$JHC = 0.7934 \cdot HDI - 0.02806 \quad (11)$$

Moreover, based on our own research, this formula was refined specifically for Kazakhstan as follows:

$$JHC = 0.8144 \cdot HDI - 0.02609 \quad (12)$$

Table 1. Estimated human capital index (JHC) values for the regions of western Kazakhstan.

Years	Aktobe Region	Atyrau Region	West Kazakhstan Region	Mangystau Region
2010	0,520	0,569	0,488	0,409
2011	0,517	0,560	0,501	0,378
2012	0,501	0,566	0,512	0,430
2013	0,502	0,553	0,488	0,441
2014	0,501	0,557	0,449	0,509
2015	0,492	0,541	0,422	0,490
2016	0,489	0,535	0,447	0,470
2017	0,491	0,534	0,489	0,488
2018	0,489	0,532	0,442	0,489
2019	0,490	0,534	0,461	0,511
2020	0,488	0,531	0,448	0,502
2021	0,501	0,537	0,476	0,525
2022	0,512	0,539	0,511	0,532

Note: compiled by the authors based on recalculation relative to the national Human Capital Index (JHC) values for Kazakhstan. The official JHC assessment for Kazakhstan for 2023 will be provided by the World Bank following its 2024-2025 study.

It should also be emphasized that the JHC values for the regions of Western Kazakhstan were calculated for the period 2010-2022. This is since the Human Capital Index for 2023 will be published by the World Bank based on expert-analytical studies conducted in 2024-2025. Accordingly, all other data used for deriving the formalizations of the economic and mathematical models are also taken for the period 2010-2022 (Table 2 and Table 3).

Table 2. JEXD values for the regions of western Kazakhstan, thousand KZT per capita.

Years	Aktobe Region	Atyrau Region	West Kazakhstan Region	Mangystau Region
2010	74,7	56,1	107,6	80,4
2011	77,2	60,6	109,0	84,7
2012	83,2	67,4	111,5	97,9
2013	89,4	75,7	113,3	99,2
2014	92,1	81,5	115,2	105,7
2015	97,3	83,3	116,0	111,4
2016	105,5	91,2	117,9	118,3
2017	113,2	93,5	119,6	117,9
2018	122,2	96,2	123,5	107,9
2019	145,1	123,1	126,5	136,4
2020	186,3	137,8	181,3	173,6
2021	201,5	153,8	208,1	196,9
2022	233,5	194,4	231,2	251,3

Note: compiled by the authors based on data from the Regional Statistics Departments of Western Kazakhstan.

The rationale for using the enterprise innovation activity indicator as the primary beneficiary of human capital formation processes is grounded in the logic of economic diversification based on an industrial-

innovation framework. Human capital emerges as the main priority and the key driver of innovation development. Accordingly, the overarching goal of long-term social policy should be to create conditions that ensure the sustainable reproduction of qualitatively new human potential.

Table 3. J_{act} values for the regions of western Kazakhstan, %.

Years	Aktobe Region	Atyrau Region	West Kazakhstan Region	Mangystau Region
2010	7,7	6,1	4,6	1,1
2011	10,8	6,6	9,1	1,2
2012	5,9	4,4	7,5	1,3
2013	6,5	5,1	5,3	2,4
2014	7,6	8,1	6,6	3,4
2015	7,0	8,0	4,1	4,0
2016	9,3	8,5	3,6	4,1
2017	10,1	8	5,3	3,5
2018	10,6	8,3	5,3	4,0
2019	10,6	9,0	5,3	3,4
2020	11,1	10,1	5,9	7,9
2021	12,5	10,1	6,9	6,3
2022	13,5	6,7	4,7	5,0

Note: compiled by the authors based on data from the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan.

Based on the data from Tables 1-3 and in accordance with the framework presented in Figure 4, the parameters were calculated, and model sets were developed for each region of Western Kazakhstan. To improve interpretability, the analysis focuses on the core relationships between human capital quality, expenditures on its formation, and innovation activity, while auxiliary models and extended specifications are presented in (Table 4).

Table 4. Economic and mathematical models of the relationship between JHC and J_{exd} in the regions of western Kazakhstan.

Regions	Economic and Mathematical Models
Aktobe Region	$Jact = - 44,787 +100,34\ JHC + 0,583\ t$ $JHC = 0,941\ J_{EXD}^{0,069}\ t^{-0,0462}$
Atyrau Region	$Jact = 47,901 -74,987\ JHC + 0,0897\ t$ $JHC = 0,638\ J_{EXD}^{0,0213}\ t^{-0,038}$
West Kazakhstan Region	$Jact = 3,05\ JHC^{1,72}\ t^{-0,0239}$ $JHC = 1,556\ J_{EXD}^{0,19}\ t^{-0,075}$
Mangystau Region	$Jact = 2,33\ JHC^{2,594}\ t^{0,425}$ $JHC = 1,208\ J_{EXD}^{0,0587}\ t^{0,103}$

Note: calculated and compiled by the authors.

All calculated economic and mathematical models are valid, with reliability coefficients ranging from R = 0,91-0,95. The time factor t, represented as a series of natural numbers, is applied to eliminate the potential negative impact of autocorrelation between the dependent and independent indices, since their formation incorporates, directly or indirectly, the population size over the period under consideration. Based on the derived model sets, we calculated the human capital quality estimates for the regions of Western Kazakhstan and conducted medium-term forecast calculations up to 2027.

1. HUMAN CAPITAL QUALITY ESTIMATES

A 1% increase in per capita spending on sectors related to human capital is associated with a 0.365% increase in innovation activity. This indicates a positive relationship, meaning that higher investment in human capital supports innovation growth in the Aktobe Region.

$$EL = EL_1 \times EL_2 = 5.296 \times 0.063 = 0.365 \quad (13)$$

This assessment confirms that increasing per capita expenditures on sectors contributing to human capital formation leads to a proportional rise in innovation activity in the Aktobe Region. In contrast, in the Atyrau Region, a 1% increase in the same type of spending is associated with a 0.119% decrease in innovation activity. This reflects a negative relationship, suggesting that such expenditures do not effectively translate into improved innovation outcomes.

$$EL = -5.593 \times 0.0213 = -0.119 \quad (14)$$

A negative elasticity value indicates that increased expenditures on human capital are not accompanied by the necessary growth in innovation activity. Moreover, innovation may even decline, which, in our view, is associated with the limited implementation of economic diversification policies in a region whose economy remains largely resource dependent. This situation hampers the development of higher-value-added industries, as previously noted with reference to the conclusions of the expert group led by Academician V. Biryukov [10] of the Russian Academy of Sciences. It should also be noted that such an economy, dependent on the volatile global hydrocarbon market, does not provide sufficient incentives for the qualitative growth of human capital.

West Kazakhstan Region: A 1% increase in per capita spending on sectors related to human capital is associated with a 0.327% increase in innovation activity, indicating a positive relationship and suggesting that such investments support innovation performance in the region.

$$EL = 1.72 \times .19 = 0.327 \quad (15)$$

Mangystau Region: A 1% increase in per capita spending on sectors related to human capital is associated with a 0.1523% increase in innovation activity, also reflecting a positive relationship, although the effect is relatively weaker compared to other regions.

$$EL = 2.594 \times 0.0587 = 0.1523 \quad (16)$$

In general, we can say that the assessment of the quality of human resources is at a high level in Aktobe and West Kazakhstan regions, at a lower-than-average level in Mangistau region and goes into negative territory in Atyrau region. These assessments, in our opinion, can be a sufficiently scientifically based basis for taking measures to adjust management decisions along the entire chain of formation and implementation of human resource potential in the considered regions of Western Kazakhstan.

2. FORECAST OF QUALITATIVE DEVELOPMENT OF THE HUMAN CAPITAL CONCEPT

Based on the built-up set of economic and mathematical tools and adjusting the volume and sectoral structures of expenditures, in accordance with the strategic measures for the formation of better human capital, developed, we can make forecast calculations for the medium-term 5-year period, starting from 2022. Thus, in the Aktobe region, the human capital index in 2027 may reach 0.543 with an increase in the indicator of average per capita expenditures on the factors of formation and development of human capital to 259.5 thousand tenge. If we talk about the qualitative aspects of the human capital, then in general, innovation activity can reach a level of more than 20%, with the value in 2022 at the level of 13.5%.

In Atyrau region, the level of innovation activity may reach 9.7%, in West Kazakhstan-6.9% and in Mangystau region-about 8%. At the same time, the level of this indicator of the quality of private housing in Atyrau region corresponds to the average indicator for the period 2019-2021, when innovation activity was in the range of 9.0-10.1%, while in 2022 it was at the level of 6.7%, with a decrease to 5% in 2023. In the other two regions West Kazakhstan region and Mangystau region-the growth of the human capital index will be

accompanied by a significant increase in innovation activity in the economy of these regions, which may indicate an increase in the qualitative aspects of human capital.

The empirical study in the article is based on a balanced panel sample of four regions of Western Kazakhstan for the period 2010-2022. The panel data structure allows us to simultaneously consider interregional heterogeneity and time dynamics of indicators, which makes this approach methodologically preferable for analyzing the relationship between the quality of human capital and innovation activity. As part of the study, two basic panel specifications were built. Economic and mathematical models of the dependence of IHC on IZ in the regions of Western Kazakhstan, assess the relationship of innovation activity with the quality of human capital, describe the dependence of the quality of human capital on average per capita expenditures on the factors of its formation in the regions in a certain time, reflect unobservable regional effects and errors. The time trend is included to account for macroeconomic and institutional shifts common to all regions. To prevent the risk of false correlations, the stationarity of variables (JHC, JZ, and Jact) was diagnosed. Considering the small number of regions (N=4), panel tests for single roots were supplemented with time tests for each region separately.

The results of Augmented Dickey–Fuller tests confirm the absence of explosive dynamics of the series when a deterministic trend is included. Panel tests were used as an auxiliary procedure, considering the limited statistical power with a small cross-section measurement. Thus, variables can be used in regression analysis without the risk of systematic bias of estimates. The potential linear relationship between explanatory variables was estimated using correlation matrices and VIF statistics. The VIF values remain below critical thresholds, which indicates the absence of serious multicollinearity and confirms the stability of the coefficient estimates. Diagnostic procedures revealed signs of heteroscedasticity and moderate error autocorrelation, typical for regional panel samples. To ensure the consistency of statistical conclusions, all models were evaluated using robust standard errors. We used clustered standard errors by region, as well as Driscoll-Kraay adjustments that allow us to consider both temporal correlation and interregional dependence. This approach corresponds to modern standards of panel econometrics and provides a correct interpretation of the significance of coefficients.

The model specification was selected based on the Hausman test. The test results indicate a correlation of unobserved regional effects with explanatory variables, which makes the fixed effects (FE) model statistically preferable. The fixed effects model is used as the main specification, while random effects estimates are given as a test of the stability of the results. The possibility of a two-way link between innovation activity and human capital is considered by evaluating lag specifications:

$$Jact_{it} = \alpha + \beta JHC_{i,t-1} + \gamma_t + \backslash mu_i + \epsilon_{it} \quad (17)$$

Using lagged variables reduces the risk of simultaneous causation. Due to the small number of regions, the use of dynamic GMM estimates is not statistically justified, so the results are interpreted as stable structural associations, rather than strict causal effects. Nevertheless, potential endogeneity may arise due to reverse causality, as higher innovation activity can stimulate increased investment in human capital. The use of lagged explanatory variables allows mitigating this issue and supports a more robust interpretation of causal relationships. To verify the reliability of the conclusions, extended stability tests were performed, considering alternative specifications with and without the inclusion of a time trend; lagged versions of explanatory variables; exclusion of the shock period 2020-2021; alternative functional forms (logarithmic and level models). The signs and order of significance of the coefficients are preserved in all specifications, which confirms the stability of empirical results. Overall, diagnostic tests confirm the robustness, validity, and stability of the estimated models.

IV. RESULTS

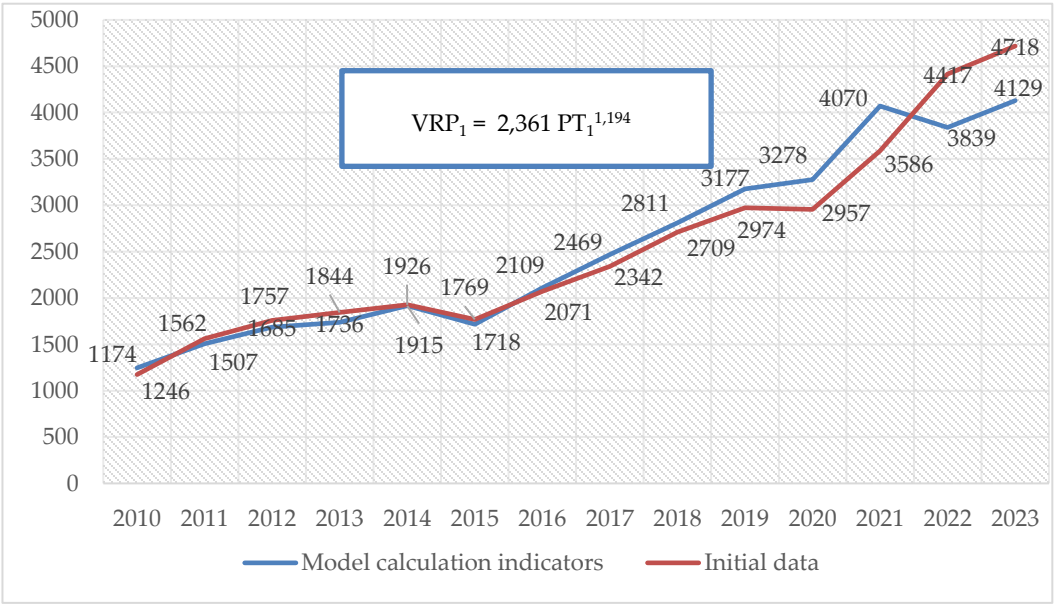
Methodological approaches were employed to model the processes of human potential formation and its transformation into human capital. For this purpose, dynamic datasets of relevant indicators covering the period 2010–2023 were compiled, and model sets were developed for all four regions of Western Kazakhstan.

For the Aktobe Region, time-series data of the selected indicators were constructed to support model development (see Table 5).

Table 5. Dynamics of indicators GRP_1, LP_1, EDU_1, HC_1, and SD_1 in Aktobe region.

Years	GRP1, billion KZT	LP1, thousand KZT	EDU1, million KZT	HC1, million KZT	SD1, million KZT
2010	1 174	2 832	47 621	4 248	5 154
2011	1 562	3 321	49 238	4 863	5 919
2012	1 757	3 647	53 913	5 234	6 266
2013	1 844	3 739	58 641	5 732	6 745
2014	1 926	4 059	61 239	6 134	7 152
2015	1 769	3 706	65 364	6 987	7 654
2016	2 071	4 401	72 498	7 598	7 984
2017	2 342	5 022	79 547	8 035	8 145
2018	2 709	5 599	87 617	8 597	8 640
2019	2 974	6 204	96 030	10 194	19 961
2020	2 957	6 270	131 231	16 865	16 162
2021	3 586	7 633	151 688	11 280	17 229
2022	4 417	7 269	182 510	8 551	22 999
2023	4 718	7 726	247 605	11 352	29 227

Note: Data from the Aktobe Regional Statistics Department.



Note: compiled by the authors.

FIGURE 5. Graphical illustration of the model's approximation properties.

Calculations for deriving the economic and mathematical models were performed using a specialized program for processing dynamic data series, based on the implementation of the well-known least square's method. First Level of the Model Set. Using the data from Table 5, this program allowed us to derive a model that best describes the relationship between gross domestic product and labor productivity:

$$GRP_1 = 2.361LP_1^{1.194} \quad (18)$$

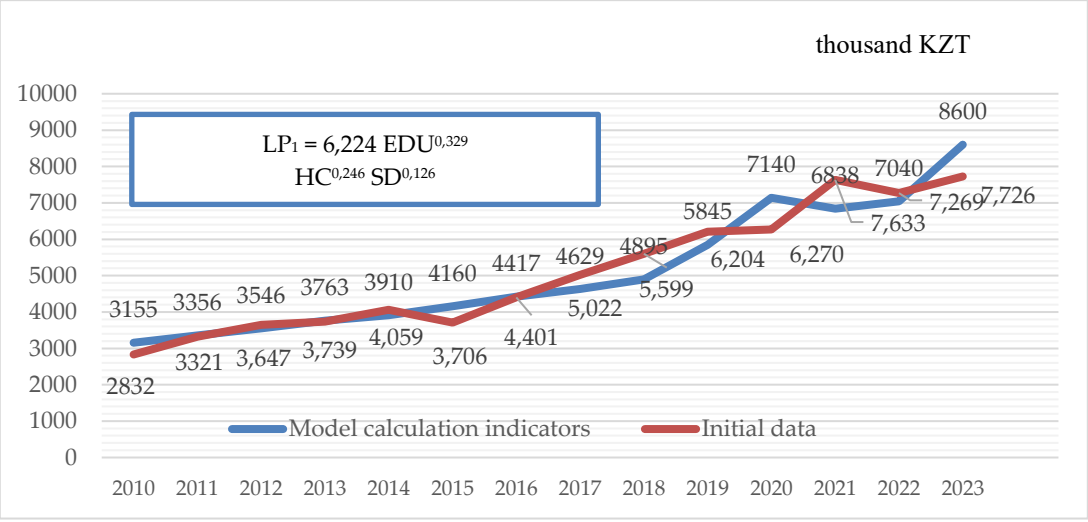
Where *GRP1* is Gross Regional Product of Aktobe Region; *LP1* is labor productivity in Aktobe Region.

The multiple correlation coefficient (R = 0.96) and the coefficient of determination (*R2* = 0,92) indicate that the identified relationship closely approximates a functional form and demonstrate the high adaptability of the developed model. This, in turn, suggests its applicability for medium-term forecasting purposes.

In particular, the high approximation characteristics of the model are also demonstrated by the Figure 5. As can be seen from the analysis of model (18), the elasticity coefficient indicates that a 1% increase in labor productivity is highly likely to result in a 1.194% increase in the Gross Regional Product of Aktobe Region. Second Level of the Model Set. Based on the calculations, we derive a model describing the dependence of labor productivity (*LP1*) on the considered factors:

$$LP_1 = 6.224 \cdot EDU^{0.329} \cdot HC^{0.246} \cdot SD^{0.126} \quad (19)$$

Again, the coefficients R = 0.96 and R2 = 0,92 indicate the high efficiency of the calculated model. The corresponding diagram is presented in Figure 6.



Note: compiled by the authors.

FIGURE 6. Graphical illustration of the model's approximation properties.

Analysis of the model parameters shows that a 1% increase in expenditures on the education system can lead to a 0.33% increase in labor productivity; expenditures on the healthcare system a 0.25% increase; and expenditures on social development a 0.13% increase. As can be seen, among these key factors, spending on education has the greatest impact on labor productivity growth, while social programs have the least, indicating an insufficient level of funding for areas directly related to improving the population's living standards.

In principle, these incremental effects can be used to inform adjustments in the region's investment policy regarding the regulation of human potential formation processes and their impact on economic growth through implementation as human capital, including at the forecasting stage. Third Level of the Model Set. Trend models of the dependence of factors on time, which can be used for forecasting calculations based on the model set over a medium-term horizon:

$$EDU_1 = 61.47 - 12.66t + 1.19t^{2;(R=0.99)} \quad (20)$$

$$HC_1 = 3.468 + 0.639t; (R = 0.80) \quad (21)$$

$$SD_1 = 4.769 + 0.389t + 0.0425t^{2;(R=0.96)} \quad (22)$$

It should be noted that the dynamics of factor development over 2010–2023 are complex, due to the instability of funding volumes from the regional budget. This necessitates, in addition to traditional linear and exponential models, the use of various models that best approximate the factor dynamics including polynomial, exponential, and moving average models, among others.

Next, in the process of forming the model set for Aktobe Region and other regions of Western Kazakhstan, to avoid excessive overcrowding of diagrams, it is considered appropriate to present diagrams only for the key models, showing trend models of factors that best illustrate the approximation capabilities of polynomial, exponential, moving average methods, and others. Using the full set of derived models, it is possible to perform medium-term economic growth forecasts and to estimate the economic efficiency of the human capital concept, according to the scheme presented this section. The medium-term forecast up to 2028 is presented in Table 6.

Table 6. Forecast of economic growth in Aktobe region considering the human capital factor, billion KZT.

Indicators	2024	2025	2026	2027	2028
EDU_1	139,3	163,6	190,2	219,2	250,5
HC_1	13,1	13,7	14,3	15,0	15,6
SD_1	20,2	21,9	23,7	25,5	27,5
LP_1, thousand KZT	7032,2	7578,6	8134,0	8694,5	9266,4
GRP_1	3690,7	4035,6	4391,1	4754,7	5130,3

Note: calculations were performed by the authors.

The analysis of the forecasted values of economic growth indicators and human capital formation factors, considering the incremental effects discussed above, allows for an assessment of the contribution of the human capital concept to the economy. For instance, in 2028, a 1% increase in expenditures on education, healthcare, and social programs may be accompanied by a 67.1 thousand KZT increase in labor productivity and, accordingly, an 80.1 billion KZT increase in the Gross Regional Product. It should be emphasized that a per-unit approach is applied in these assessments (incremental result per 1% increase in the influencing factor). This approach, on the one hand, allows avoiding dependence on specific absolute values and, on the other hand, provides the possibility of calculating the effect on the total resource volume, which is variable in regional economies. In accordance with formula (8) presented in the previous subsection, the overall economic efficiency, taking into account the cumulative effect of the human capital concept in 2028, can be estimated as follows:

$$\Delta GRP_{1,total} = (1 + 3.605)\Delta GRP_1 = 4.605\backslash cdot375.6 = 1729.6\ billion\ KZT \quad (23)$$

For the sake of accuracy, it should be emphasized that a significant portion of this cumulative effect is distributed across sectors in other regions of Kazakhstan, whose enterprises interactively contribute to the formation of human resource potential in Aktobe Region. Alongside the assessment of economic efficiency, it is also possible to estimate social efficiency, expressed as the growth in the share of the Gross Regional Product allocated to funding regional social programs. The calculations show that, on average, over the analyzed period 2010–2023, this share amounted to 0.2%, while in the forecast period 2024-2028, it is expected to average 0.51%, reaching 0.532% by 2028. Table 7 presents the data used for constructing the model set.

Table 7. Dynamics of indicators GRP_2, LP_2, EDU_2, HC_2, and SD_2 in Atyrau region.

Years	GRP_2, billion KZT	LP_2, thousand KZT	EDU_2, million KZT	HC_2, million KZT	SD_2, million KZT
2010	2 844	10 335	23 167	2 756	3 624
2011	3 791	11 634	25 796	2 893	3 892
2012	3 613	10 859	29 873	2 931	4 196

2013	3 977	11 596,	34 862	3 127	4 532
2014	4 341	12 717	38 524	3 561	4 723
2015	4 217	12 844	40 359	3 788	4 856
2016	5 201	16 011	45 845	3 973	4 987
2017	5 948	17 815	47 544	4 763	5 136
2018	7 819	22 969	50 144	4 946	5 268
2019	9 327	26 521	64 994	4 841	8 888
2020	7 738	22 572	75 347	6 970	7 417
2021	10 628	30 442	87 568	5 996	8 341
2022	13 725	37 496	114 703	7 345	11 558
2023	14 950	39 718	163 993	12 130	13 222

Note: Data from the Statistics Department of Atyrau Region.

Calculations carried out following a similar scheme allowed us to develop a corresponding set of econometric-mathematical models for the Atyrau region. First Level of the Model Set. Using the program and the data from Table 7, a model was derived that best describes the dependence of the Gross Regional Product on labor productivity:

$$GRP_2 = -820.42 + 0.387 \cdot LP_2 \quad (24)$$

Where $GRP_2$is Gross Regional Product of the Atyrau region; $LP_2$is Labor Productivity in the Atyrau region. The values of the multiple correlation coefficient R = 0.998 and the coefficient of determination $R2$ = 0.996 indicate that the identified relationship is practically functional and reflect the high adaptive properties of the derived model. This confirms its full suitability for medium-term forecasting purposes. Analysis of the elasticity coefficient shows that a 1% increase in labor productivity would lead to a 1.12% increase in the Gross Regional Product, which, based on 2023 data, could amount to approximately 167.4 billion KZT.

Second Level of the Model Set describing the dependence of labor productivity $LP2$ on expenditures for education, healthcare, and social development is derived. Calculations using the program yielded the following model:

$$LP_2 = 1342.9 + 87.4EDU_2 - 469.7HC_2 + 2470.94SD_2 \quad (25)$$

The coefficients R=0.97 and $R2$=0.94 indicate a high reliability of the derived model. Analysis of the elasticity coefficients for the factors in model (24) shows that a 1% increase in expenditures on the education system is associated with a 0.26% increase in labor productivity, while a 1% increase in social program expenditures corresponds to a 0.79% increase. At the same time, a 1% increase in healthcare expenditures leads to a 0.116% decrease in labor productivity. The latter may indicate that healthcare spending in Atyrau Region is insufficient to stimulate growth in labor productivity. As can be seen, in this region too, the factor of income determining the education level of the population has the greatest impact on labor productivity growth. Third Level of the Model Set. The calculations reveal the following auxiliary trend models:

$$EDU_2 = 7.34 - 9.7t + 1.364t^{2;(R=0.98)} \quad (26)$$

$$HC_2 = 3.048 - 0.305t + 0.057t^{2;(R=0.91)} \quad (27)$$

$$SD_2 = 1.714t^{0.635;(R=0.89)} \quad (28)$$

Using the entire set of derived models, it is possible to perform medium-term economic growth forecasts and to estimate the economic efficiency of the human capital concept, in accordance with the scheme presented in Figure 1 of the previous subsection of this section. The authors conducted forecast calculations using the derived set of models (25-27), as presented in Table8.

Table 8. Forecast of economic growth in Atyrau region considering the human capital concept, billion KZT.

Indicators	2024	2025	2026	2027	2028
EDU_2	168,7	201,3	236,6	274,7	315,4
HC_2	11,3	12,8	14,3	16,0	17,8
SD_2	11,2	11,9	12,5	13,1	13,8
LP_2, thousand KZT	38539,9	42252,9	46201,9	50301,6	54581,6
GRP_2	14078,1	15513,4	17040,0	18624,9	20279,4

Note: calculations were performed by the authors.

Analysis of the forecasted economic growth indicators and the factors shaping human capital, considering the aforementioned marginal effects, allows for an assessment of the contribution of the human capital concept to the economy. In 2028, a 1% increase in expenditures on education, healthcare, and social development may be associated with an increase in labor productivity of 50.98 thousand KZT, corresponding to an increase in the Gross Regional Product of 56.92 billion KZT. Considering the cumulative effect, the total increase in the Gross Regional Product in 2028 may amount to:

$$\Delta GRP_{2,total} = (1 + 3.605)\Delta GRP_2 = 4.605\backslash cdot1654.5 = 7619\ billion\ KZT \quad (29)$$

Regarding social efficiency, calculations show that if, on average, during the analyzed period 2010-2023, the share of *GRP* growth allocated to increases in social program expenditures was 0.076%, then in the forecast period 2024–2028 it is expected to average 0.042%. This, in our view, does not ensure a substantial increase in the actual volume of funding for social development. An information base is compiled for conducting model calculations.

Table 9. Dynamics of indicators GRP_3, LP_3, EDU_3, HC_3, and SD_3 in west Kazakhstan region.

Years	GRP_3, billion KZT	LP_3, thousand KZT	EDU_3, million KZT	HC_3, million KZT	SD_3, million KZT
2010	1 049	3 034	57 854	2 056	4 982
2011	1 358	3 696	58 964	2 098	5 234
2012	1 763	4 905	60 589	2 137	5 629
2013	1 781	4 890	61 598	2 398	5 951
2014	1 988	5 453	62 879	2 624	6 437
2015	1 710	4 772	63 489	2 876	6 729
2016	2 033	5 702	64 854	2 982	7 183
2017	2 338	6 440	66 245	3 018	7 516
2018	2 791	7 544	68 243	3 126	8 626
2019	2 946	7 977	69 965	3 690	8 816
2020	2 734	7 576	101 955	3 022	14 121
2021	3 533	9 663	117 678	4 019	15 932
2022	4 435	11 627	135 178	4 250	18 522
2023	4 811	12 440	184 877	8 442	26 408

Note: Data from the Statistics Department of West Kazakhstan Region.

Similarly, to the previous regions, calculations were carried out to derive economic and mathematical models. First level of the model complex. Calculations performed using this program and based on the data from Table 5 made it possible to derive a model that most accurately determines the dependence of the gross regional product on labor productivity:

$$GRP_3 = -164.86 + 0.392 \cdot LP_3 \quad (30)$$

Where GRP_3 is Gross Regional Product of the West Kazakhstan Region; LP_3 is Labor Productivity in the West Kazakhstan Region. The values of the multiple correlation coefficient R = 0.999 and the coefficient of determination R2 = 0.998 indicate that the identified relationship is functional and demonstrate the high adaptive properties of the derived model. The analysis of the elasticity coefficient shows that a 1% increase in labor productivity leads to a 1.106% increase in the GRP, which, according to 2023 data, could amount to approximately 53.2 billion tenge.

Second level of the model complex. In accordance with the algorithm applied above, a model of the dependence of labor productivity LP3 on the considered factors is derived:

$$LP_3 = 11.23 \cdot EDU_3 \cdot HC_3^{0.245} \cdot SD_3^{1.55} \quad (31)$$

Once again, the coefficients R = 0.97 and R2 = 0.94 indicate the high efficiency of the derived model. The analysis of the elasticity coefficients of the factors shows that a 1% increase in expenditures on the education system leads to a 1.406% decrease in labor productivity, whereas a 1% increase in expenditures on healthcare and social programs results in an increase in labor productivity by 0.245% and 1.55%, respectively. As can be seen, the factor of expenditures on social programs has the strongest impact on labor productivity growth. At the same time, it can be concluded that expenditures on education do not contribute to an increase in labor productivity. Third level of the model framework. Trend models describing the dependence of the factors on time:

$$EDU_3 = 43.38e^{(0.088t);(R=0.98)} \quad (32)$$

$$HC_3 = 1.13 + 0.295t; (R = 0.76) \quad (33)$$

$$SD_3 = 8.057 - 1.653t + 0.1964t^{2;(R=0.98)} \quad (34)$$

Table 10. Forecast of economic growth in the west Kazakhstan region considering the human capital concept, billion KZT.

Indicators	2024	2025	2026	2027	2028
EDU3	162,4	177,3	193,6	211,5	230,9
HC3	5,6	5,8	6,1	6,4	6,7
SD3	27,5	31,9	36,7	41,9	47,6
LP3, thousand KZT	15182,5	17072,3	18979,2	20823,5	22681,3
GRP3	5795,6	6537,5	7286,1	8010,2	8739,5

Note: calculations were performed by the authors.

Using the derived system of models (19-23), forecast calculations were performed (Table 10). The analysis of the obtained forecast values of economic growth indicators and human capital formation factors, considering the incremental effects discussed above, makes it possible to assess the significance of the human capital concept for the economy of the West Kazakhstan Region. In 2028 a 1% increase in expenditures on education, healthcare, and social development is expected to result in an increase in labor productivity by 88.2 thousand KZT and, consequently, in an increase in gross regional product by 34 billion KZT. The estimate of the overall economic efficiency in 2028, considering the cumulative effect, can be expressed as follows:

$$\Delta GRP_{3,total} = (1 + 3.605)\Delta GRP_3 = 4.605\backslash cdot729.3 = 3358.4 \; billion \; KZT \quad (35)$$

About social efficiency, the calculations indicate that while during the analyzed period of 2010-2023 the average share of GRP growth allocated to increased expenditures on social programs amounted to 0.16%, in the forecast period of 2024-2028 this share is expected to rise to an average of 0.68%, reaching 0.78% by 2028. As in the previous cases, an information base was constructed for the purposes of model estimation (Table 11).

Table 11. Dynamics of indicators GRP_4, LP_4, EDU_4, HC_4, and SD_4 in Mangystau region.

Years	GRP_4, billion KZT	LP_4, thousand KZT	EDU_4, million KZT	HC_4, million KZT	SD_4, million KZT
2010	1 485	6 707	25 015	13 273	3 039
2011	1 868	6 914	30 289	11 684	3 308
2012	1 765	5 688	34 829	15 808	3 909
2013	2 075	6 329	37 363	16 080	3 807
2014	2 418	8 010	41 929	16 260	4 870
2015	2 124	6 590	45 278	17 927	5 458
2016	2 463	7 802	47 732	20 753	6 605
2017	3 296	10 320	57 809	11 168	7 775
2018	3 803	10 752	61 340	3 033	7 947
2019	3 685	10 088	75 131	3 440	15 433
2020	3 074	8 526	103 116	6 770	13 193
2021	3 627	9 412	122 527	6 520	14 789
2022	4 401	11 224	160 079	9 038	20 965
2023	4 866	12 313	214 629	14 411	27 934

Note: Data from the Mangystau Region Statistical Department.

The following section presents calculations for deriving the system of econometric-mathematical models for analysis and forecasting. First level of the model framework. Calculations based on the data in Table 11 allowed us to derive a model that best describes the dependence of the gross regional product on labor productivity:

$$GRP_4 = 5.053 \cdot LP_4^{1.436} \quad (36)$$

Where GRP_4 is Gross Regional Product of the Mangystau Region; *LP4* is Labor Productivity in the Mangystau Region. The values of the multiple correlation coefficient R = 0.97 and the coefficient of determination *R2* = 0.94 indicate that the identified relationship exhibits high adaptive quality. Analysis of the elasticity coefficient shows that a 1% increase in labor productivity is associated with a 1.436% increase in the region's GRP, equivalent to 69.2 billion KZT in 2023. Second level of the model framework. Econometric-mathematical model of labor productivity as a function of the following factors:

$$LP_4 = 7852.7 - 1.8 \cdot EDU_4 - 104.18 \cdot HC_4 + 215.44 \cdot SD_4 \quad (37)$$

The coefficients R = 0.87 and R2 = 0.76 indicate that the model falls within an acceptable range for forecasting and analytical studies. Analysis of the parameters of model (25) shows that a 1% increase in expenditures on the education and healthcare systems is associated with a decrease in labor productivity of 0.016% and 0.143%, respectively, whereas the social development factor is associated with an increase of 0.248%. These results suggest that particular attention should be paid to the development of the education and healthcare systems.

Third level of the model framework. Trend models describing the dependence of the factors on time:

$$EDU_4 = 21.6e^{(0.1462t);(R=0.98)} \quad (38)$$

$$HC4 = \frac{HC_{4(t-1)} + HC_{4(t)}}{2} (R = 0.92) \quad (39)$$

$$SD_4 = 4.785 - 1.148t + 0.1673t^{2;(R=0.98)} \quad (40)$$

Using the derived system of econometric-mathematical models, the author conducted forecast calculations (Table 12).

Table 12. Forecast of Economic Growth in Mangistau Region Considering the impact of the Human Capital Concept, billion KZT.

Indicators	2024	2025	2026	2027	2028
EDU_4	213,9	224,1	259,3	300,2	347,4
HC_4	13,4	14,8	16,4	18,3	20,4
SD_4	25,2	29,2	33,6	38,3	43,4
LP_4, thousand KZT	11500,5	12198,0	12915,9	13656,9	14451,8
GRP_4	4327,1	4708,9	5111,9	5538,2	6006,9

Note: calculations were performed by the authors.

Analysis of the forecasted values of economic growth indicators and the factors shaping human capital (HC) allows for an assessment of the economic efficiency of the HC concept. Specifically, in 2028, a 1% increase in expenditures on education, healthcare, and household income is projected to be associated with an increase in labor productivity of 27.3 thousand KZT and, correspondingly, an increase in the gross regional product of 16.3 billion KZT.

The relatively lower efficiency of the HC concept in Mangistau Region, compared to the other three regions of Western Kazakhstan, is, in our view, attributable to insufficient stimulation of labor productivity growth through the education and healthcare factors. The assessment of total economic efficiency in 2028, considering the cumulative effect, can be estimated as follows:

$$\Delta GRP_{4,total} = (1 + 3.605)\Delta GRP_4 = 4.605\backslash cdot468.7 = 2158.4\ billion\ KZT \quad (41)$$

Regarding social efficiency, the calculations indicate that if, on average, during the analyzed period 2010-2023, the share of GRP growth allocated to increased spending on social programs amounted to 0.425%, then in the forecast period 2024-2028 it may average 0.94%. It should be emphasized that, in assessing the efficiency of the human capital (HC) concept, one could also estimate the cumulative effect for the entire Western Kazakhstan subregion. However, in this study, we limited our calculations to the additional economic effect for each individual region since a comprehensive approach would encounter the problem of "double counting" across regions. Indeed, the same interrelated sectors that contribute to the development of human resource potential in one region may also play this role for other regions, which could lead to overestimated total cumulative effects for the subregion.

Nevertheless, this does not remove from consideration the possibility of estimating a synergistic effect. As noted in the previous subsection, such an assessment at the regional level requires addressing complex tasks related to the development of theoretical, methodological, and scientific bases, as well as the improvement of statistical and information support. In the present study, however, we attempt to apply a simplified methodology within the available official statistical framework, specifically, by estimating changes in the competitive advantages of the subregion based on integrated measures for developing the human capital concept. Thus, it is evident that increasing expenditures in the education, healthcare, and social development sectors, and their effective utilization across the entire chain of human resource potential formation processes, forms the basis for enhancing human capital quality, which, in turn, yields return in the form of increased competitive advantages for the economies of the Western Kazakhstan regions.

In this context, it should be noted that accelerating economic growth through investments in people's knowledge and skills remains a highly relevant challenge. Undoubtedly, such transformational changes impose specific requirements on public management. Within the framework of the Human Capital Development Project developed by the World Bank Group, the need to implement nationwide strategies addressing multiple significant barriers to human resource potential formation and qualitative human capital development is emphasized, alongside expenditure management models that are often far from optimal in terms of final outcomes. The results suggest that improving the quality of human capital requires prioritizing investments in education, healthcare, and social development, with a particular focus on their effectiveness in generating innovation outcomes.

V. CONCLUSION

As a result of our scientific research and analysis, new modern approaches to assessing the quality of human capital are proposed: The first direction is the necessary application of consistent efforts, not limited to the narrow framework of political and economic cycles. At the same time, the most important condition for truly radical changes in the development of the human capital is determined by the steady fulfillment of long-term obligations that fit into several political and economic cycles. The rich and diverse world experience proves that consistency in setting these tasks at the forefront is not only possible, but also a sufficiently effective approach to the problem of forming and developing high-quality human capital. The second direction is the mutual coordination of various programs for the development of industries and industry complexes, which should proceed from the understanding that investments in the formation and development of high-quality human capital are determined not only and not so much by a narrowly focused policy for the development of only social sectors. In fact, investment resources in the real sector of the economy can also have a significant indirect impact through the labor market on the processes of forming human capital of the necessary quality condition. The third direction is the formation of a high-quality evidence base for the development of verified, well-founded strategies for the development of a high-quality private sector. This will allow a deeper study of the interrelationships of various aspects and components of factors in the processes of formation and development of human capital [27].

It is in this vein that the article shows systematic measures to increase personal capital, based on which we conducted research on the qualitative aspects of human capital in the regions of Western Kazakhstan. The results obtained because of the study are new, as this is the first time such an assessment has been carried out in a regional context. The applied models were developed during the research process and are not trivial, which is confirmed by their verification. In conclusion, it is important to emphasize that the concept of human capital of the necessary quality condition does not manifest itself by itself, it must be nurtured by the state itself. According to the World Bank experts, in countries where the motives that motivate the actions of governments, local authorities, and directly producers of educational and other social services are in a harmonious combination, significant progress is being made in improving the quality of human capital.

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Author Contributions

All authors made an equal contribution to the development and planning of the study.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability

Statement Data is available from the authors upon request.

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