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HUMAN CAPITAL FOR SUSTAINABLE REGIONAL DEVELOPMENT[6]

The research aimed at the construction of the ranking of the human capital index in the regions of the Russian Federation based on the available data on the significant factors of sustainable development. Based on the premise that the components of the Human Capital Index calculated by the World Bank coincide with the Sustainable Development Goals from Agenda 2030 "Transforming our world", the authors construct a Regional Rating of Human Capital Development in Russia using measurable indicators for 85 Russian regions for Targets 3 and 4 from National Sustainable Development Goals Indicator Set. The indicators were grouped into three pillars (subsets): Health, Education and Living standard, each pillar consisting of 2-4 sub-pillars and 2-6 indicators. All data for the indicator's calculation is taken from official statistics. No expert assessment is used. The research methodology is based on generalized modified principal component analysis (GMPCA), verified by the authors' previous research. The study reflects an integrated approach to assessing the efforts of Russian regional authorities in human capital development. The research lays the foundation for regular analysis of the rating and dynamics of its components in the Russian regions, which will allow for an assessment of the current state and potential of human capital development in Russian regions and can serve to improve regional socio-economic policy.

Keywords: principal components analysis; human capital; rating of regions
JEL: C38; E24; Q01; R11

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1. Introduction

Human beings, their knowledge and competences, in today's knowledge economy are becoming the main factor for successful economic development. Therefore, human capital development is not only a task for employees and employers, but primarily a task for the government.

Despite the fact that human capital is one of the main drivers of economic growth, it is not easy to make a convincing case for investing in it. As early as Alfred Marshall pointed to the relationship between the “illiquidity” of individual assets and their limited investment potential: "The worker sells his work, but he himself remains his own property: those who bear the expenses of rearing and educating him to receive but very little of the price for his services in later years. Consequently the invest the investment of capital in him is limited by the means, the forethought, and the unselfishness of the parents” (Marshall, 1993, p. 466). Although this statement seems somewhat exaggerated in today's context of countries' huge investments in human capital, it captures the essence of the problem (Verenikin, 2005).

According to G. Becker, "human capital is formed by investments in people, among which we can name education, production training, health care costs, migration and the search for information on prices and income" (Becker, 2003, p. 39). A large share of these investments in our country, and in other countries of the world, falls on the shoulders of the state.

Investment in human capital is becoming increasingly important as the characteristics of labour are changing under the influence of rapid technological progress. The World Bank's “The Changing Nature of Work” report states that the labour market increasingly value workers with better socio-behavioural skills such as “aptitude for teamwork, empathy, conflict resolution, and relationship management” (World Bank, 2019, p. 50). In this report, experts revise the issue of measuring human capital by focusing on outcomes rather than inputs, i.e. costs, and propose the construction of a human capital index (HCI) to assess the role of health and education in the productivity of the next generation of workers (World bank, 2019, p. 56).

The HCI measures the amount of human capital, "child born in 2018 can expect to attain by age 18, taking into account the risks of poor health and poor education that prevail in the country in which the child was born during that same year” (World bank, 2019, p. 12). This means that children born in a particular year will have certain educational opportunities and face certain health risks as they grow up and that higher levels of education and better health will ultimately affect the productivity of the next generation of workers.

The HCI has three components:

1. Child survival from birth to school age (measured using under-5 mortality data);
2. Educational attainment (measured by the expected number of years of schooling, taking into account the quality of that schooling).[7]

[7] In order to compare children's learning, the World Bank is developing a new comprehensive database of test scores from international student assessment programmes covering some 160 countries.

3. Health level (measured through adult survival rate and prevalence of stunting among children under 5 years of age).

We will not elaborate further on the HCI, since not all indicators have been calculated for Russia (in particular, official statistics of the Russian Federation do not collect data on stunting, which probably had a negative impact on the final result of Russia), we note only that the Russian Federation ranks 34th, the first five places are taken by Singapore, Republic of Korea, Japan, Hong Kong and Finland, the last – the poorest countries of Africa.

According to the World Bank, human capital is one of the most important factors of sustainable economic growth. Sustainable economic growth is a crucial point for sustainable development, a concept developed and promoted by the World Bank.

More than thirty years ago, the concept of sustainable development proclaimed meeting "the needs of the present generation without compromising the ability of the future generations to meet their own needs" (Brundtland, 1987). Over time, specific goals, targets and indicators have been formulated. The UN resolution of 25 September 2015 "Transforming our world: The 2030 Agenda for Sustainable Development" presented 17 Sustainable Development Goals and 169 targets that define the vector of development: social, economic and environmental priorities.

The components of the Human Capital Index (survival rate, schooling, and health) are directly linked to at least three global goals to be achieved by the countries of the world by 2030.

Although the principles of sustainable development have been included in a number of official documents of the Russian Federation for more than 20 years, they are not yet widely applied in practical political decisions.

However, some very concrete steps in this direction have already been taken. For example, in July 2020, the first "Voluntary National Review of the 2030 Agenda for Sustainable Development" was launched at a high-level political forum under the auspices of the UN Economic and Social Council (ECOSOC). Non-governmental Ecological Vernadsky Foundation took part in the preparation of the Review. Rosstat is actively monitoring the SDG indicators and the information is available on the Rosstat web portal in the section "Sustainable Development Goals".

It is easy to see that the three components of the HCI (survival rate of children under 5, quantity and quality of education, and health status of adults) are linked to the achievement of Goal 3, "Good Health and Well-Being", and Goal 4, "Quality Education", because, according to the report developers, "achievement of quality education lays the foundation for improving people's living conditions and for sustainable development" (Sustainable Development Goals in the Russian Federation, 2020).

Thus, in constructing the ranking we will try to calculate the human capital index in the regions of the Russian Federation based on the available data on the significant factors of sustainable development.

In addition, we will further compare our rating with the results obtained in the "Human Development Index in Russia for 2019" calculated by the Analytical Center for the

Government of the Russian Federation (Human Development Index in Russia: Regional Disparities, 2021). In calculating this index, the Analytical Center for the Government of RF applied the methodology of the UN Development Programme "Human Development Index" (Human Development Indices and Indicators, 2018): for each Russian region, the gross regional product (GRP) is adjusted for the non-distributable part of the country's GDP, and the GRP is adjusted for price differences. By comparing two indexes we try to estimate the difference of our index and HDI calculated on the basis of official UN methodology.

2. Data and Methodology

From the National SDG Indicator Set, we selected measurable regional indicators for 2019, representing data for Targets 3 and 4. We have presented these targets as indicators of the Russian regions' human capital development rankings. We have also added indicators for the population's living standards. The indicators are grouped into three subsets (pillars): health, education and living standard, each section consisting of subsections comprising from 2 to 6 indicators (see Table 1). The calculations were based on open official statistics, mainly from the official website of the Federal State Statistics Service (Rosstat). The principal component loadings are calculated for 85 regions.

The research methodology is based on principal component analysis (PCA), which is widely used in multivariate statistics, including regional studies (see, for example, Doukas et al, 2012; Petrişor et al, 2012; Tan, Lu, 2015; Gavrilets et al., 2019).

The methodology is constructed on an integral indicator. An integral indicator is an indicator that aggregates a group of indicators of alternatives or sub-indices based on these indicators. The advantages of the integral indicator are that it allows aggregating of multi-dimensional information about alternatives and allows one to see the overall picture of the alternative, with the integral indicator it is easier to capture the attention of the public (Saltelli et al., 2006). A single integral indicator is preferable to searching for trends in several indicators at once.

There are approaches to compiling integral indicators based on weighting initial indicators (Poledníková, Melecký, 2017; Aivazyan, 2006; Yang, Ou, Hsu, 2019), ranking indicators (Aleskerov, 2013), and calculating performance (Lissitsa, 2003). Singh et al. (2008) provide a synthesis of approaches to measuring sustainability based on indicator weighting. The article summarizes the experience of measuring the sustainability of companies, cities, regions, countries, and economic activities. The approaches for each stage of compiling an integral indicator are highlighted.

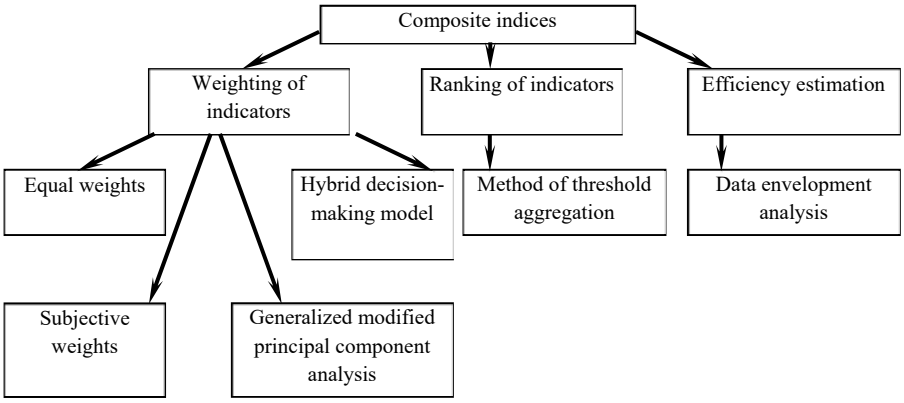
Table 1. Indicators for calculating the Regional Rating of Human Capital Development in Russia

Pillar	*Sub-pillar*		*Indicators*	*Weight*, %*
A. Health care	A1. Infant mortality	A1.1	Mortality of children aged 0 – 4 years (per 1,000 live births)	3.90
		A1.2	Infant mortality (per 1,000 born alive)	3.92
	A2. Survivability. Health	A2.1	Mortality from blood circulatory system diseases (per 100,000 population)	3.87
		A2.2	Mortality from neoplasms, including malignant neoplasms (per 100,000 population)	3.87
		A2.3	Morbidity with a first-time diagnosis of drug abuse (per 100,000 population)	3.99
		A2.4	Morbidity with a first-time diagnosis of alcoholism and alcoholic psychosis (per 100,000 population)	3.99
		A2.5	Number of fatalities in road accidents, persons (per 100,000 population)	4.00
		A2.6	Number of settlements with a population of more than 100 up to 2,000 that are beyond the reach of a healthcare provider or its structural subdivision providing primary healthcare	3.99
	A3. Survivability. Sanitation	A3.1	Sanitary status of drinking water supply, number of samples (from distribution network) not meeting hygienic standards as a percentage of the total number of samples analyzed	4.00
		A3.2	Sanitary condition of urban atmospheric air, number of samples that do not meet hygienic standards as a percentage of the total number of samples tested	3.98
		A3.3	Sanitary condition of the soil, number of samples that do not meet hygienic standards as a percentage of the total number of samples tested	4.00
	A4. Survivability. Preventive care	A4.1	Coverage of citizens by preventive health examinations	3.99
		A4.2	Proportion of the population who are systematically involved in physical education and sport	3.99
		A4.3	Healthy life expectancy	4.01
B. Education	B1.Education. Accessibility	B1.1	Net enrolment of children under 3 years of age in pre-primary education	4.00
		B1.2	Gross enrolment ratio in secondary vocational education programmes as a % of the population aged 15-19 years	3.98
		B1.3	Gross enrolment ratio in higher education – Bachelor's, Specialist's and Master's degree programmes, as a percentage of the population aged 17-25 years	3.99
	B2.Education. Effectiveness	B2.1	Proportion of pupils in general education institutions aged 10 and over who are under the basic level of training in accordance with the Federal Standards for Education	4.00
		B2.2	Index of change in the educational attainment of pupils in general education institutions in basic general education programmes	4.00
C. Living standard	C1.Welfare	C1.1	GRP at PPP, million roubles (GRP multiplied by the ratio of regional subsistence minimum to federal subsistence minimum)	3.97
		C1.2	GRP per capita, RUB	3.97
		C1.3	Average cash income per capita, roubles	3.91
		C1.4	Proportion of the population with cash incomes below the minimum subsistence level (% of the total population of RF region)	3.97
	C2. Regional expenditures on human capital	C2.1	Human capital development expenditures, % of GRP	4.00
		C2.2	Increase in human capital development expenditures, % of GRP	4.00

** weights are calculated by generalized modified principal component analysis in Gretl[8].*
Source: compiled by the authors on the basis of the National SDG Indicator Set – https://rosstat.gov.ru/sdg/national.

[8] Gretl is an abbreviation of GNU Regression, Econometrics and Time-series Library (statistics and econometrics software package).

Figure 1. Approaches to construction of composite indices



Source: Verenikin, Makhankova, Verenikina, 2021.

Poledníková and Melecký (2017) distinguish three approaches to determining weights: equal weights for criteria, a subjective determination of weights and a determination of weights based on statistical approaches.

Subjective weighting means that weights are determined on the basis of expert opinion, opinion polls or an analytic hierarchy process (AHP) (Singh et al., 2008). The advantage of subjective scales is that they are transparent and easy to understand. The disadvantage of subjective weights is that they reflect the preferences of a certain group of individuals, but users of the integral indicator can change and for them, the ratio of indicators may be irrelevant.

Statistical or objective methods of weighting include approaches that are based on mathematical calculations. Poledníková and Melecký (2017) include methods based on performance boundary analysis, the shortest distance to the target, conjoint analysis and factor or regression analysis. Singh et al. (2008) highlight the principal component method and regression analysis, noting that equal or expert weights are more commonly used.

When considering methods for comparing alternatives, it is important to note the approach called data envelopment analysis (DEA). This method assesses the technical effectiveness of certain decision-making units (DMUs) and ranks them according to their effectiveness. First, a number of input and output parameters are selected for each alternative (DMU). Generally, inputs refer to the resources used and outputs refer to the goods and services produced. Measurement of technical efficiency consists of comparing the actual output to the maximum possible output for a given amount of resources (Lissitsa, 2003).

The different approaches used to compare alternatives (Figure 1) have both advantages and disadvantages. The diversity of existing approaches is due to the fact that each of them meets the requirements of researchers in its own way. In our opinion, to measure the sustainable development of companies, it is necessary to exclude approaches that use expert or subjective assessments of company indicators, the approach should be automated, mathematically and

economically justified. Approaches that use equal or subjective weights lose because they are not sufficiently convincing for an external user. The threshold aggregation method of compiling an integral indicator requires the ranking of indicators into three gradations, which cannot be done for sustainable development indicators without expert judgement. The performance-based approach requires a strict division of indicators into inputs and outputs (inputs and outputs), a division that is debatable.

An alternative, quite a common approach in multivariate statistical analysis, tested in many studies, which avoids subjective estimates in comparing a variety of parameters and factors, is the principal components method.

Suppose that each j-th region (j=1,…,m) is characterized by a number of parameters $\{x_i\}_{i=1}^{n}$. In general, we are dealing with a matrix of input data $X = \begin{pmatrix} x_{11} & \cdots & x_{1m} \\ \vdots & \ddots & \vdots \\ x_{n1} & \cdots & x_{nm} \end{pmatrix}$, in which vector columns correspond to information about particular regions. Denote the corresponding covariance matrix by $\Sigma = \begin{pmatrix} \sigma_{11} & \cdots & \sigma_{1n} \\ \vdots & \ddots & \vdots \\ \sigma_{n1} & \cdots & \sigma_{nn} \end{pmatrix}$.

The key question is how to select appropriate weighting factors for the specific indicators of the region x_i so as not to rely on subjective judgements.

Using principal components analysis one can transform the input data matrix X into a new set of artificially uncorrelated variables: $Z = \begin{pmatrix} Z_1 \\ \vdots \\ Z_n \end{pmatrix} = \begin{pmatrix} z_{11} & \cdots & z_{1m} \\ \vdots & \ddots & \vdots \\ z_{n1} & \cdots & z_{nm} \end{pmatrix} = LX$, where $Z_1, \dots, Z_m$ – are vectors of the principal components, $L = \begin{pmatrix} l_{11} & \cdots & l_{1n} \\ \vdots & \ddots & \vdots \\ l_{n1} & \cdots & l_{nn} \end{pmatrix}$ is the linear orthogonal transformation matrix.

The fraction of total variation of initial data explained by the k-th principal component can be calculated as the ratio of the corresponding characteristic root of the matrix Σ and the sum of its eigenvalues: $\rho_k = \frac{\lambda_k}{\sum_{k=1}^{n} \lambda_k}$.

Using the modified principal components approach (Aivazyan, 2006) one can consider the weighted sum $y_{1j} = \sum_{i=1}^{n} l_{1i}^2 x_{ij}$ instead of commonly used z_{1j} as an aggregate indicator of economic activity. This avoids negative estimates of the principal components as constituent elements of the composite index.

In order to retain the information content of initial data we propose to use a generalized modified principal components approach (Verenikin, 2018) verified in our previous studies (See, e.g., Verenikina, Verenikin, 2019; Verenikin et al, 2021) so as to calculate the aggregate indicator of regional human capital development as a weighted sum of values y_{kj}, that correspond to every principal component ($k = 1, \dots, l$):

$$I_j = \sum_{k=1}^{l} \rho_k y_{kj} = \sum_{k=1}^{l} \rho_k \sum_{i=1}^{n} l_{ki}^2 x_{ij} = \frac{\sum_{k=1}^{l}\left(\lambda_k \sum_{i=1}^{n} l_{ki}^2 x_{ij}\right)}{\sum_{k=1}^{l} \lambda_k} = \sum_{i=1}^{n} \frac{\sum_{k=1}^{l} \lambda_k l_{ki}^2}{\sum_{k=1}^{l} \lambda_k} x_{ij} = \sum_{i=1}^{n} \sigma_i x_{ij},$$

where $\sigma_i = \frac{\sum_{k=1}^{l} \lambda_k l_{ki}^2}{\sum_{k=1}^{l} \lambda_k}$ is the weight of the i-th indicator that characterizes regional human capital development within the aggregate index calculated using the generalized modified principal components analysis.

The modified principal components y_{kj} are weighed here by the fractions of variation in initial data explained by the corresponding principal components ρ_k. Thus we avoid any loss of data variance. The explaining capability of the proposed index extends to the total variance of initial variables. A distinctive feature of the proposed composite indicator is that it is not sensitive to subjective preferences regarding the relative importance of specific factors of regional human capital development. In contrast to the weighting coefficients, which are based on subjective judgments of experts and are obtained a priori, prior to data analysis, the objective weights σ_i (see Table 1) are posteriorly estimates, since they are calculated on the basis of the analysis of initial data.

We use the aggregate indicators calculated via generalized modified principal component analysis to arrange the regional rating of human capital development (Table 2).

It is necessary to normalize initial indicators within the range from one to ten in order to obtain a uniform increasing influence of all factors under consideration on the level of the resulting aggregate index.

We scale indicators to a ranking gradation from 1 to 10 according to the following idea. The sample contains both negative and positive impact indicators. Thus, all mortality and morbidity indicators of Section A (subsections A1 and A2), all indicators related to the sanitary condition of water, land and air (subsection A3), as well as indicator B2.1 (proportion of underskilled pupils) and indicator C1.4 (share of the population with income below the subsistence minimum) are negative, and the condition "the less, the better" applies to them. The remaining indicators are positive and are subject to the "more is better" condition. If the indicator corresponds to the "the more, the better" case, we fit it to the 1-10 ranking scale in the same way as before: $x_{ij}^n = 1 + 9\left(\frac{x_{ij} - x_{ij}^{\min}}{x_{ij}^{\max} - x_{ij}^{\min}}\right)$, where x_{ij}^n is the normalised variable, $x_{ij}^{\max}$ and $x_{ij}^{\min}$ – are the "best" and "worst" values of the original indicator respectively. If the indicator corresponds to the "the less, the better" case, the following normalisation transformation is applied: $x_{ij}^n = 1 + 9\left(\frac{x_{ij} - x_{ij}^{\max}}{x_{ij}^{\min} - x_{ij}^{\max}}\right)$, where x_{ij}^n is the normalised variable, $x_{ij}^{\max}$ and $x_{ij}^{\min}$ are the "worse" and "better" values of the original indicator respectively.

The rating is a linear combination of the entire set of modified principal components. Thus, it can be seen as a composite of partial indices that summarize the weighted modified estimates of the principal components for each data pillar, i.e. for each section. These sub-indices form the region's ranking for each section and provide insights into the factors affecting the level of human capital development and the potential for improvement.

3. Results

The results are presented in Table 2. Moscow leads, followed by St. Petersburg, Yamalo-Nenets, Nenets and Khanty-Mansi Autonomous Area, Belgorod Region and the Republic of Tatarstan. Outsiders include the Pskov and Amur regions, the Karachay-Cherkessia Republic, the Transbaikal Territory and the Jewish Autonomous Area.

Table 2. Regional Rating of Human Capital Development in Russia

RF region	Integral indicator value	Place in the ranking
Moscow city	7,11233	1
Saint Petersburg city	6,72552	2
Yamal-Nenets Autonomous Area	6,69358	3
Nenets Autonomous Area	6,67086	4
Belgorod region	6,42850	5
Republic of Tatarstan	6,41691	6
Khanty-Mansi Autonomous Area – Ugra	6,37279	7
Astrakhan region	6,28132	8
Samara region	6,25874	9
Krasnoyarsk region	6,15772	10
Komi Republic	6,08431	11
Lipetsk region	6,08015	12
Magadan region	6,05642	13
Sakhalin region	6,03877	14
Udmurtian Republic	6,03555	15
Vologda region	6,00496	16
Krasnodar region	5,98669	17
Moscow region	5,98021	18
Tyumen region (without Autonomous Area)	5,95391	19
Chechen Republic	5,92608	20
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Ivanovo region	5,75031	76
Republic of Tuva	4,59766	77
Republic of Altay	5,54130	78
Kurgan region	4,72529	79
Altai region	5,48321	80
Pskov region	5,25058	81
Amur region	5,92608	82
Karachayevo-Chircassian Republic	5,69154	83
Trans-Baikal territory	4,46106	84
Jewish Autonomous region	4,83791	85

Source: composed by the authors.

By grouping the results by federal districts, we obtained an aggregated regional ranking in terms of human capital development (see Table 3), with the Central Federal District in the lead.

Having decomposed the integral ranking, we calculated sub-indices that summarized the weighted modified loadings of the principal components for each data pillar. These sub-indices form the region's ranking for each pillar and provide insights into the factors affecting human capital development and the potential for improvement (see Table 4).

Table 3. Aggregated regional rating of human capital development by federal districts

Federal District of the Russian Federation	*Integral indicator value*	*Place in the rating*
Central	105,251	1
Volga	80,264	2
Northwestern	74,054	3
Far Eastern	57,896	4
Siberian	54,183	5
Southern	45,739	6
North Caucasus	39,539	7
Ural	35,263	8

Source: composed by the authors.

Table 4. Leaders and outsiders in the sub-indices of Regional Rating of Human Capital Development in Russia

	Pillar A.Health		
1	Republic of Tatarstan	76	Amur region
2	Moscow city	77	Irkutsk region
3	Belgorod region	78	Oryol region
4	Yamalo-Nenets Autonomous Area	79	Krasnoyarsk Territory
5	Nenets Autonomous Area	80	Novgorod region
6	Khanty-Mansi Autonomous Area	81	Pskov region
7	Republic of Ingushetia	82	Jewish Autonomous Region
8	Astrakhan Region	83	Primorye Territory
9	Republic of Udmurtia	84	Trans-Baikal Territory
10	Chechen Republic	85	Chukotka Autonomous Area
	Pillar B. Education		
1	Saint-Petersburg city	76	Jewish Autonomous Region
2	Moscow city	77	Republic of Buryatia
3	Tyumen region	78	Chukotka Autonomous Area
4	Tomsk region	79	Kabardino-Balkarian Republic
5	Samara region	80	Republic of Altai
6	Novosibirsk Region	81	Trans-Baikal Territory
7	Republic of Tatarstan	82	Republic of Tuva
8	Nizhny Novgorod Region	83	Republic of Daghestan
9	Vladimir region	84	Chechen Republic
10	Oryol region	85	Republic of Ingushetia
	Pillar C. Living standard		
1	Moscow city	76	Astrakhan region
2	Yamal-Nenets Autonomous Area	77	Jewish Autonomous Region
3	Nenets Autonomous Area	78	Republic of Kalmykia
4	Chukotka Autonomous Area	79	Chelyabinsk region
5	Sakhalin region	80	Smolensk region
6	Khanty-Mansi Autonomous Area	81	Republic of Mari El
7	Trans-Baikal Territory	82	Kabardino-Balkarian Republic
8	Magadan Region	83	Republic of Ingushetia
9	Saint Petersburg city	84	Republic of Mordovia
10	Moscow region	85	Republic of Khakassia

Source: composed by the authors

Among the leaders in subindex A. “Health”: Tatarstan, Moscow and Belgorod Region; for subindex B. "Education": the federal cities of St. Petersburg and Moscow and Tyumen,

Tomsk and Samara regions; for sub-index C. “Living standard": Moscow, Yamalo-Nenets, Nenets and Chukotka Autonomous Areas, Sakhalin Region.

Among the outsiders in subindex A. “Health”: Pskov Region, Primorsky Region, Trans-Baikal Territory, Jewish and Chukotka Autonomous Area; for sub-index B. "Education": Trans-Baikal territory, Republics of Tuva, Dagestan, Chechnya and Ingushetia; by sub-index C. "Living standard": Republics of Mari El, Kabardino-Balkaria, Ingushetia, Mordovia and Khakassia.

4. Discussion

Let us compare our rating “Regional Rating of Human Capital Development in Russia” with the "Human Development Index in Russia: regional disparities” which has been composed by the Analytical Centre for the Government of the Russian Federation since 2015. Let us take the latest calculation data, for 2019 (see Table 5).

Table 5. Comparative table of the positions of RF regions in the human development ratings (the first 15 and the last 10)

Regions of the Russian Federation	Position in the Regional Rating of Human Capital Development in Russia	Position in the Human Development Index in Russia: regional disparities	Deviation
Moscow city	1	1	0
Saint Petersburg city	2	2	0
Yamalo-Nenets Autonomous Area	3	4	+1
Nenets Autonomous Area	4	5	+1
Belgorod region	5	10	+5
Republic of Tatarstan	6	6	0
Khanty-Mansi Autonomous Area	7	11	+4
Astrakhan region	8	3	-5
Samara region	9	16	+7
Krasnoyarsk region	10	12	+2
Komi Republic	11	17	+6
Lipetsk region	12	19	+7
Magadan region	13	14	+1
Sakhalin region	14	8	-6
Republic of Udmurtia	15	22	+7
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Ivanovo region	76	77	+1
Republic of Tuva	77	85	+8
Republic of Altai	78	82	+4
Kurgan region	79	74	-5
Altai region	80	73	-7
Pskov region	81	76	-5
Amur region	82	71	-11
Karachayevo-Chircassian Republic	83	79	-4
Trans-Baikal Territory	84	81	-3
Jewish Autonomous Region	85	84	-1

Source: Regional Rating of Human Capital Development in Russia calculated by the authors, Human Development Index in Russia: regional disparities created by the Analytical Centre for the Russian Government (see Human Development Index in Russia, 2021, pp. 10-13)

As we can see from Table 5, there is little divergence in most positions (13 positions for 0-4 positions in the ranking, 11 positions for 5-8 positions). At the same time, the Amur Region diverges by 11 places, the region ranks 82 in our ranking, and 71 in the Human Development Index. The reason for this divergence is the relatively high position of the region in the Living standard pillar (43rd place), which is determined by an average share of the population with incomes below the subsistence level (15.7%, with a maximum of 34.1% among all regions and a minimum of 5.6%), and increase in human capital expenditures (1.14% of GRP, with a maximum of 1.8% and a minimum of 0.9% among all regions).

To investigate the relationship between regional human capital rankings, we compared them using Kendell and Spearman rank correlation coefficients (Table 6).

Table 6. Rank correlation coefficients for the ratings of human capital development

Kendall's rank correlation coefficient	0,38
P-value	0,14
Spearman rank correlation coefficient	0,524
P-value	0,21

Source: calculated by the authors based on Regional Rating of Human Capital Development in Russia and Human Development Index in Russia: regional disparities.

Kendell's rank correlation coefficient is defined as the difference in rank probabilities of matching and inversion and is calculated according to the formula: $\tau_K = (P - Q)/(P + Q)$, where P is the number of matches, Q is the number of inversions[9] (Kendall M. et al. 1975).

The Spearman rank correlation coefficient that takes into account the difference in ranks is calculated according to the formula: $\tau_S = 1 - \frac{6\sum_{i=1}^{n}(u_i - v_i)^2}{n(n^2-1)}$, where $(u_i - v_i)$ – is the rank difference of the i-th observation, n – is the number of observations.

Observations in our study refer to RF regions that have rank-places in the respective rankings. A single value of Kendell and Spearman coefficients means complete coincidence between the two rankings, a value of zero means no correlation between the ranks, a value equal to -1 means a complete inversion of the rankings.

A pairwise comparison across the sample of regions simultaneously in the compared rankings yields Spearman and Kendell rank correlation coefficient values of 0.38 and 0.52, respectively (Table 6). Since the coefficient values more than P-value in each case – we reject the null hypothesis. Thus, the rank correlation coefficient is statistically significant and the rank correlation relationship between the two ratings of human capital development is significant.

[9] Coincidence refers to the simultaneous excess of the ranks of the i-th observations over the ranks of the j-th observations, and inversion refers to the case where the rank of the i-th observation of the first ordering is greater than the rank of the j-th observation, and the rank of the i-th observation of the second ordering is lower than the rank of the j-th observation.

In order to understand what the ranking positions are related to, it is important to pay attention to the structure of the generated integral indicator, in particular the weights that were picked up by the generalized modified principal component analysis (see Table 1).

The indicators with the highest weight are: A4.3. Healthy life expectancy, 4.01%, A2.5 Number of fatalities in road accidents (4,00%), A3.1. Sanitary status of drinking water supply, 4%, A3.3 Sanitary condition of the soil, 4%, B1.1. Net enrolment of children under 3 years of age in pre-primary education, 4%, B2.1. The proportion of pupils who are under the basic level of training (4%), B2.2. Index of change in educational attainment, 4%, C2.1. Human capital development expenditures (4,00%) and C2.2. Increase in human capital development expenditures, 4%.

The indicators with the lowest weighting are: A2.1. Mortality from blood circulatory system diseases, 3.87%, A2.2. Mortality from neoplasms, including malignant neoplasms, 3.87%, A1.1. Mortality of children aged 0 – 4 years, 3.90%, C1.3. Average cash income per capita, 3.91%, A1.2. Infant mortality, 3.92%.

Though the indicators with the highest weights can be treated as more important factors for human capital quality, the weights of indicators are very close to each over, so we can't make the conclusion, that only crucial factors for human capital development should be taken into account in regional policy.

Poses and cons for regional human capital development can be evaluated by analyzing the structure of the integral indicator of each region, where we can explore the contribution of each indicator to the integral value of the rating and compare the position of each indicator with the average for the sample. Based on the comparison, it is possible to identify indicators that are drivers of growth, to provide recommendations for improving performance in those areas where the relevant potential is present.

For instance, there are 3 neighbouring regions in the Northern-East of the Central district: Ivanovo, Kostroma and Yaroslavl, historically closely linked regions, which political centres are within 100 km of each other.

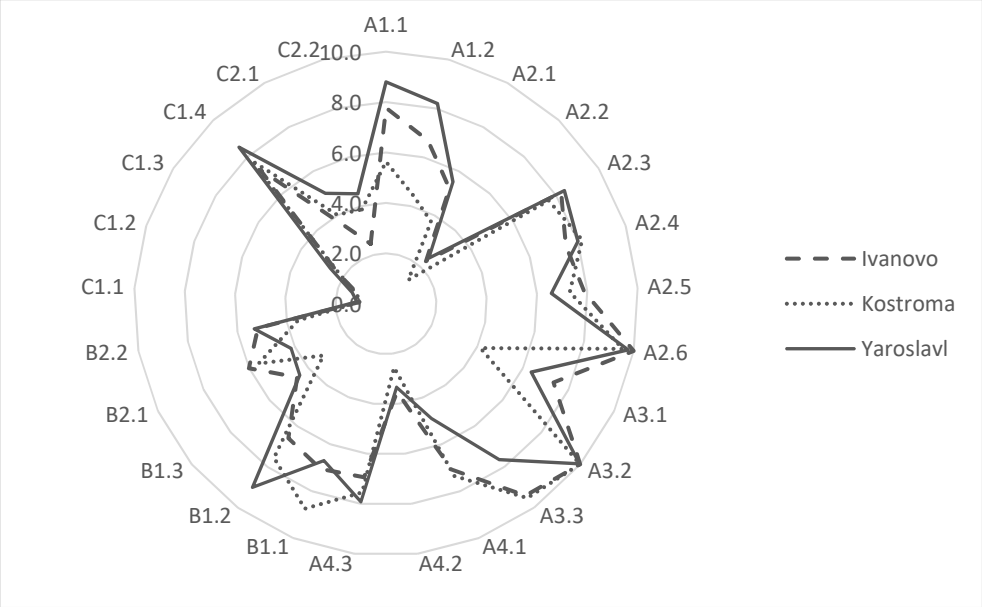
Table 7. Indices and sub-indices of Regional Rating of Human Capital Development in Russia for selected regions

Region	Position in the Regional Rating of Human Capital Development in Russia	Pillar A.Health	Pillar B. Education	Pillar C. Living standard
Ivanovo region	76	33	21	69
Kostroma region	66	74	29	44
Yaroslavl region	26	44	20	34

Source: composed by the authors on the basis of Regional Rating of Human Capital Development in Russia.

Yaroslavl ranks significantly higher than its nearest neighbours. What is the reason for its failure? If we look at the values of sub-indices, we see that Kostroma lags behind in Pillar A. «Health» and Ivanovo in Pillar C. «Living Standards». Further decomposition of the integral index requires analysis of indicator values, for which the region is lagging and identification of reasons for this situation (see Figure 2).

Figure 2. Decomposition of integral indicator of Regional Rating of Human Capital Development in Russia for Ivanovo, Kostroma and Yaroslavl regions



Source: composed by the authors on the basis of Regional Rating of Human Capital Development in Russia.

So, these are specific issues that are the responsibility of regional authorities. For example, Kostroma is seriously lagging by indicator A1.1. Mortality of children aged 0 – 4 years and indicator A3.1. Sanitary status of drinking water supply. Obviously, the solution to these problems lies in the development of the health care system in the regions (including in the frames of the national project Demography), and in a renewal of the central water supply system due to its significant deterioration. Ivanovo region, in its turn, is lagging behind by human capital development expenditures (indicators C2.1. and C2.2.), so public administrations should ensure that the region's investment in human capital will increase.

5. Conclusion

Thus, our rating methodology reflects a comprehensive approach to assessing individual aspects of regional development. The rating provides an integrated assessment of the current state of human capital development in Russian regions. We used only official statistical data published by federal agencies, so there are some shortcomings associated with the lack of sufficient statistical information. The research base needs to be expanded in the future. Nevertheless, we do not use expert estimates, which require complex and costly research, making the calculations much simpler and more objective.

In fact, our survey lays the foundation for regular (e.g. once a year) analysis of the level of human capital development in the Russian regions. The study of factors determining the regions' positions in the ranking can be used to improve socio-economic policy in Russian regions. Obviously, in order to improve the level of human capital development, more attention and investment should be directed towards healthcare and education projects.

References

Aivazyan, S. A., Stepanov, V. S., Kozlova, M. I. (2006). Measuring the synthetic categories of the quality of life of the region's population and identifying key areas for improving socio-economic policy (on the example of the Samara Region and its municipalities). – Applied Econometrics. №2 In Russian. (Aivazyan S.A., Stepanov V.S., Kozlova M.I. Izmerenie sinteticheskih kategoriy kachestva zhizni naselenia regiona i vyyavlenie klyuchevyh napravleniy sovershenstvovania sotsialyno-ekonomicheskoy politiki (na primere Samarskoy oblasti i ee munitsipalnyh obrazovaniy) // Prikladnaya ekonometrika. 2006. №2).

Aleskerov, F. T., Pislyakov, V. V., Subochev, A. N. (2013). Construction of journal rankings in economics using methods of collective choice theory // Preprint WP7/2013/03. – Moscow: HSE Publishing House. In Russian. (Aleskerov F.T., Pislyakov V.V., Subochev A.N. Postroenie reytingov zhurnalov po ekonomike s pomoshtyyu metodov teorii kollektivnogo vybora //Preprint WP7/2013/03. – M.: Izd. dom VShE, 2013.

Becker, G. (2003). The Economic Approach to Human Behavior. Moscow: State University Higher School of Economics.

Brundtland, G. H. (1987) Our Common Future: Report of the World Commission on Environment and Development. Geneva, UN-Document A/42/427. https://digitallibrary.un.org/record/139811.

Doukas, H., Papadopoulou, A., Savvakis, N., Tsoutsos, T., Psarras, J. (2012). Assessing Energy Sustainability of Rural Communities Using Principal Component Analysis. – Renewable & Sustainability Energy Reviews, 16(4), pp. 1949-1957, doi: 10.1016/j.rser.2012.01.018.

Gavrilets Y. N., Nikitin S. A., Chernenkov M. V. (2019). Aggregated indices of people's opinions on the quality of life in Russian regions. Economics and mathematical methods, 55(1), pp. 101-115, doi: 10.31857/S042473880004045-8. In Russian. (Gavrilets Yu. N., Nikitin S. A., Chernenkov M. V. Agregirovannye indeksy mneniy naselenia o kachestve zhizni v regionah Rossii // Ekonomika i matematicheskie metody, 2019, 55(1), pp. 101-115)

Human development indices and indicators: Statistical update 2018. UNDP report https://hdr.undp.org/system/files/documents//2018humandevelopmentstatisticalupdatepdf.pdf (Accessed on 20.08. 2022).

Human Development Index in Russia: regional disparities. (2021). Analytical Centre for the Government of the Russian Federation. – https://ac.gov.ru/uploads/2-Publications/analitika/2022/ICR_2021_long.pdf (Access on 20.07. 2022).

Kendall M., Chetyrkin E. M., Entov R. M. (1975). Rank correlations. – M.: Statistics. In Russian. (Kendall. M., Chetyrkin E.M., Entov R.M. (1975). Rangovye korrelyatsii. – M.: Statistika).

Lissitsa A., Babicheva T. (2003) Data Envelope Analysis (DEA). A modern methodology for determining production efficiency //Halle: Institute of agricultural development of central and Eastern Europe. In Russian. (Lissitsa A., Babicheva T. Analiz obolochki dannyh (DEA). Sovremennaya metodika opredelenia effektivnosti proizvodstva //Halle: Institute of agricultural development of central and Eastern Europe.).

Marshall, A. (1993). Principles of economics. Eighth Edition. Palgrave Macmillan.

National SDG Indicator Set – https://rosstat.gov.ru/sdg/national (Accessed on 26.07. 2022).

Petrişor, A.-I., Ianoş, I., Iurea, D., Văidianu, M.-N. (2012). Applications of Principal Component Analysis Integrated with GIS. Procedia Environmental Sciences, 14, pp. 247-256, doi: 10.1016/j.proenv.2012.03.024.

Poledníková E., Melecký L. (2017) Weighting Methods for Constructing Composite Indices in Regional Development // The 11th International Days of Statistics and Economics. Conference Proceedings. Prague.

Saltelli A., Munda G., Nardo M. (2006). From complexity to multidimensionality: The role of composite indicators for advocacy of EU reform //Tijdschrift voor Economie en Management. – V. 51. – №. 3.

Sustainable Development Goals in the Russian Federation. 2020: Brief statistical digest / Rosstat – https://rosstat.gov.ru/sdg (Access on 20.07. 2022)

Tan, F., Lu, Zh. (2015). Study on the interaction and relation of society, economy and environment based on PCA-VAR model: As a case study of the Bohai Rim region, China. – Ecological indicators, 48, pp. 31-40, DOI: 10.1016/j.ecolind.2014.07.036.

Verenikin A. O. (2005). Human capital: conceptual foundations and peculiarities of manifestation. USA – Canada: Economics, Politics, Culture, N 3, pp. 85-100. In Russian. (Verenikin A.O. Chelovecheskiy kapital: kontseptual'nye osnovania i osobennosti proyavlenia // SShA – Kanada: ekonomika, politika, kulytura, 2005. №3. S.85-100).

Verenikin, A. O., Makhankova, N. A., Verenikina, A. Y. (2021). Measuring the sustainability of large Russian companies' development. – Russian Journal of Management, 19(3), pp. 237-287. https://doi.org/10.21638/spbu18.2021.301. In Russian. (Verenikin, A.O., Makhankova, N. A., Verenikina, A.Yu. (2021). Izmerenie ustoychivosti razvitia krupnyh rossiyskih kompaniy. Rossiyskiy zhurnal menedzhmenta, 19(3), 237–287).

Verenikina, A., Verenikin, A. (2019). Principal components approach to estimation of environmental responsibility of Russian regions. The 13th International Days of Statistics and Economics, Prague, Czech Republic, Conference Proceedings, pp. 1588-1598. doi:10.18267/pr.2019.los.186.159.

Voluntary national review of the implementation of the 2030 Agenda for Sustainable Development.- https://www.economy.gov.ru/material/file/dcbc39abeafb0418d9d48c06c958e454/obzor.pdf (Access on 26.07. 2022).

World Bank. (2019). World Development Report 2019: The Changing Nature of Work. Washington, DC: World Bank. doi:10.1596/978-1-4648-1328-3. – https://www.worldbank.org/en/publication/wdr2019 (Accessed on 16.11. 2022).

Yang, C. C., Ou, S. L., Hsu, L.C. (2019). A Hybrid Multi-Criteria Decision-Making Model for Evaluating Companies' Green Credit Rating. – Sustainability. V. 11, №. 6.

Zhgun, T. V. (2017). Construction of the integral characteristic of the quality of life of the subjects of the Russian Federation with the help of the method of principal components. – Economic and Social Changes: Facts, Trends, Forecast, No. 2 (50), pp. 214-235. In Russian. (Zhgun T.V. Postroenie integralynoy harakteristiki kachestva zhizni subaektov Rossiyskoy Federatsii s pomoshtyyu metoda glavnyh komponent. //Ekonomicheskie i sotsialynye peremeny: fakty, tendentsii, prognoz, №2 (50), 2017, 214-235).