Human capital development in the global-knowledge economy

Nail Gabdullin[*]

¹Kazan Federal University, Institute of Management, Economics and Finance, 42008 Kazan, 18 Kremlyovskaya street, Russia

Abstract. The national economy is as competitive as its human capital is effectively capitalized in modern hypercompetitive global markets. The world digital technologies contribute to the globalization of the economy and accelerate the accumulation of human capital by digitizing jobs, providing the population and households with electronic services and data mining technologies. The article analyzes the structure of multivariate data on the factors of human capital development, e-education and the use of ICT by households in Russian regions. The average annual values of the relevant factors of monitoring the development of the information society in the Russian Federation for the period from 2010 to 2017 were selected as factors of each object of analysis. The reliability of the research results is ensured by applying standardization and rationing of the initial matrix of factors, reducing the dimension of the normalized matrix of factors using the PCA method, cluster analysis using the method of EM-maximizing expectations and the hierarchical clustering method. The author has built a rating of regional clusters of the Russian Federation, differing in the quality of human capital depending on the development of electronic infrastructure, availability of digital resources and the features of the social environment.

1 Introduction

Functioning of the global knowledge-based economy is largely driven by the synchronous development of information and communication technologies (ICT), software, digital platforms and services. Globalization of the knowledge economy and digital technologies render a significant impact on the state and dynamics of human capital development. On the one hand, firms can get an access to human capital around the world while using a global network of information portals, on the other hand, the employees obtain access to the global labor market as well. Creating a new generation of workforce equipped with modern high-performance competencies for the efficient and advanced labour to obtain high professional mobility under the influence of informatization is becoming possible not only in the process of formal education, training and learning-by-doing, but is being determined by life

---

[*] Corresponding author: nail56@yandex.ru

conditions, Internet and network information resources, as well as ICT implementation, by households and population[1,2].

Supranational digital technologies contribute to the economy globalization and accelerate the development of new qualities of human capital through the jobs digitalization, providing people and households with electronic services, IoT capabilities and big data processing technologies. The empirical research has proved that human capital and ICT have a positive impact on the organization performance efficiency [3,4,5], social development and the knowledge production sphere growth rate acceleration [6].

The entry of human capital into the digital age started with the organization of open digital portals, which change the way people interact with the spheres of education, health care, training, culture, leisure and other social services provided in electronic form. Richard D. Johnson and Hal J. Hugh pointed out that the transition to digital interfaces and e-services had a profound impact on the human capital economy [7,8,9]. Computer analysis process based on business results renders informtion to HR managers about the expected business results of specific actions related to human capital management or specifies actions necessary to achieve a certain business result. „This will free the staff from performing routine tasks. More time will be devoted to engaging employees and managers in high-impact business processes including recruitment, hiring, succession provision, planning, training and career development [10]."

Human capital development takes place through knowledge accumulation and new skills mastering, essencial for successful progress in ever changing society, whereas the development of ICT takes place through the digitalization of social change [11,12,13], economic growth and social progress [14]. Thus, generally recognized consequences of ICT implementation turn out to be: interactivity intensification, increase in markets efficiency, reduction of information asymmetry and costs for obtaining and using information as well as the global coverage of markets by information services [15].

Training and professional development are priorities in the models of the digital development of the society. These activities are considered key measures for human development [16]. At mastering any skills it is important to develop measures, which express the state of readiness to expand the use of information and new technologies to develop knowledge. It is offered even to consider measuring the integral indicator of such readiness - the basic literacy level / illiteracy rate [17,18]. Fundamental digitalization framework is formed by the R&D activity aimed at public goods production growth and acquisition of competitive advantages. Being an integral part in the process of new knowledge generating, research activity provides facilities for the digital economy development [19].

Some empirical studies of economic growth have attempted to assess the role of human capital and ICT as the determinants of long-term economic growth effectiveness reasoning from indicators of human capital and ICT-based literacy [20,21]. Such indicators usually include: school enrolment comprising secondary special and higher education [22]; education costs; years of study; the employees'educational level and the degree of ICT implementation by households and the population, ICT application infrastructure, development of e-services. This statistical approach is reflected in the system of indicators *Monitoring the Development of the Information Society in the Russian Federation* [23].

2 Methods

The initial statistical data of the information society development monitoring in the Russian Federation (RF) are presented in the form of "object-property" matrix:

$$\begin{pmatrix} x_1^{(1)}(t) & x_1^{(2)}(t) & .... & x_1^{p}(t) \\ x_2^{(1)}(t) & x_2^{(2)}(t) & .... & x_2^{p}(t) \\ .... & .... & .... & .... \\ x_n^{(1)}(t) & x_n^{(2)}(t) & ..... & x_n^{(p)}(t) \end{pmatrix} \quad\quad (1)$$

$$t = t_1, t_2,..., t_n,$$

where $x_i^{(j)}(t_k)$ - the value of the j-th analyzed factor characterizing the state of the i-th subject of the RF at the time t_k. Matrix (1) forms a space-time sample, where n subjects of the RFare subjected to statistical survey. And the values p characterizing the subjects of the RFare fixed in successive moments of time $t_1, t_2, ..., t_n$. It is obvious that record (1) defines a certain statistical series (namely n pieces) "object-property" matrixes. We can also say that the matrix data contains realizations of p-dimensional time series ($x^{(1)}(t), x^{(2)}(t)$,...,

$x^{(p)}(t)$).

For the purpose of the statistical structuring and identification of the interrelations between the analyzed factors, such big data of multidimensional observations, as a rule, are subjected to statistical processing with the aim of reducing dimensionality of the investigated factor space for concise explanations of the nature of the analyzed multidimensional data. The potential for such reduction of the analyzed multivariate data is based on the assumption, according to which there is a small (in comparison with the numeral p of the initial analyzed factors $x^{(1)}, x^{(2)},...,x^{(p)}$) the numeral p' of factors-determinants (e.g., principal components) which can be accurately described both as the observed variables of constituent entities of the RF, i.e. all the elements of the matrixes (1) as well as all the elements determined by these variable properties (characteristics) of the analyzed statistics population.

Statistical studies have shown that a system using fewer factors, each of which is a combination of a large number of factors directly measured at the object, leads to a quite satisfactory classification of objects in terms of specificity. These fundamental settings are inherent in the essence of the linear transformation of the original system of factors reducing the dimension, and this transformation is carried out by the principal component analysis (PCA).

We will choose the average values of the Human capital and E-education factors in information society development monitoring in the RFfor the period of 2010-2017 as values of factors for each subject of the Russian Federation. Implementation of the PCA method to reduce the dimensionality of the analyzed factor space enables to obtain preliminary structuring of multidimensional data. Software implementation of the RSA method is made in the integrated development environment RStudio.

3 Results

Let us first reduce factors for "Human capital" group. The resulting biplot graph shows the scatterplot of the RF regions in the space of the first two principal components. The analysis of the scattering graph made possible to implement pre-visualization of clusters for the RFconstituent entities. Serial numbers of the RFsubjects are presented in Appendix 1. A

number of objects with numbers: 10, 24, 18, 28, 42, 47, 64, 66, 69, 74, 75, 84 are located apart. This means that they differ from other subjects of the RFby the special characteristics of human capital.
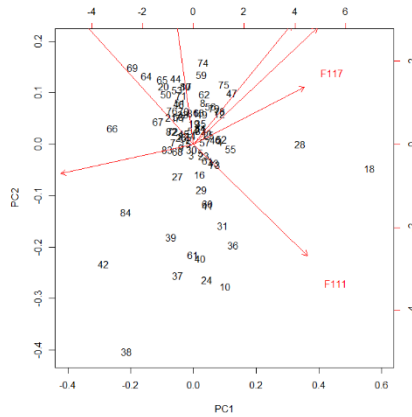

Fig. 1. Biplot Graph plotted according to the factors in "Human capital" group

Human capital development can be accelerated through the implementation of cluster policies based on a differentiated approach to individual regional clusters to improve the skills and abilities of employees and to achieve competitive advantages in terms of human capital. Therefore, it seems expedient to conduct a cluster analysis of the RFsubjects by the selected factors of "Human capital" set. Several probabilistic models are used to determine the optimal number of clusters. The evaluation of the BIC (Bayesian Information Criterion) is carried out for selecting the best model. Data structuring through cluster analysis has been made by means of the expectation maximization method (EM-Expectation Maximization) and Ward Hierarchical Clustering method. The scatterplot with the localization of three clusters is shown in figure 2.

Further on, a dendrogram with 4 clusters has been constructed using Ward's Hierarchical Clustering Method, (Fig.3).
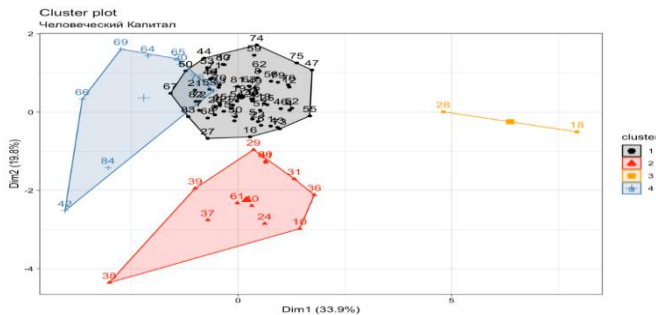

Fig. 2. Scatterplot (visualization of cluster analysis results by EM method)

This classification procedure of hierarchical type "at the output" is not completed by the final version of dividing the population of the RFsubjects into classes. With its help, it is possible to form a general visual representation of the stratification structure of the RFsubjects' population in the form of a specially arranged graph - dendrogram.
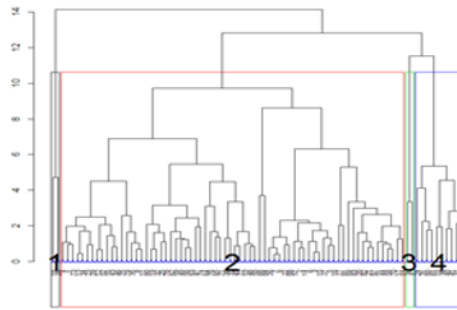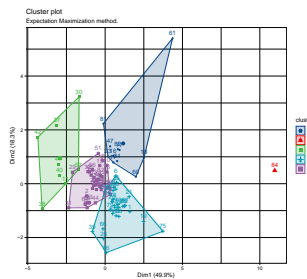
Fig. 3. Dendrogram of hierarchical cluster analysis by Ward's method

Now we proceed to reduce the group of factors "E-education". Visualization of the factors contribution to the principal components is represented in the biplot graph by the corresponding factor loads (Fig. 4).
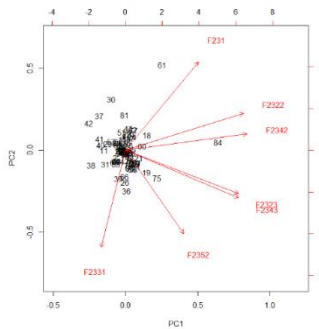
Fig. 4. Biplot graph according to the set of factors of the group "E-education"

The resulting image shows a scatterplot of the objects under examination. These are RF regions in the space allocated to the first two principal components. Let us move on to clustering of the RFsubjects by E-education factors. Clustering by five clusters turns out to be the most informative (Fig. 5).

Fig. 5. Scattering diagram (visualization of cluster analysis results by EM method)

Then we move on to hierarchical clustering by Ward's Hierarchical Clustering Method (Fig. 6).
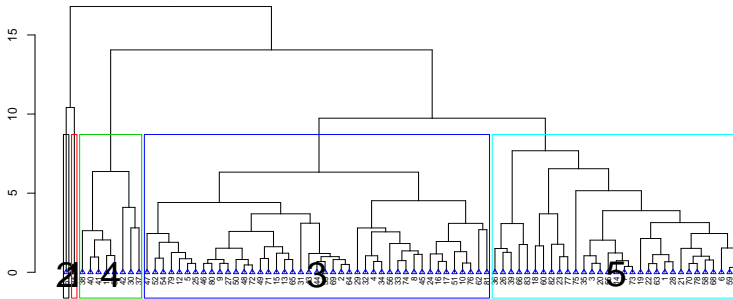
Fig. 6. Dendrogram of hierarchical cluster analysis by Ward's method

4 Conclusions

The application of the PCA method which leads to a decrease in the dimension of the factor space, makes possible to give a brief explanation of the nature of multidimensional data under analysis and solve a number of applied problems of statistical analysis and modeling. Among such decisions, it is necessary to distinguish primarily the following:

- visualization of the initial data by projecting them onto a specially constructed plane;
- simplification of modeling and interpretation of the statistical conclusions obtained due to the desire for conciseness of the models under study.

Social and economic development cannot be achieved without accelerated digital technologies accumulation and effective use of human capital. Digital technologies are creating a new institutional mechanism effectively promoting growth of total factor productivity, high staff mobility and reducing the shortage of highly skilled workers.

The exposed clusters substantiate the impact of digitalization on improving the quality of human capital in the subjects of the RFwhich differ in the level of development of electronic infrastructure, social conditions and features of the business environment. Digital technologies support human development and provide competitive advantages for regions being the part of clusters with a high level of human capital development. The availability of highly developed human capital focused on certain areas makes possible to attract international investment in such regions and poses new challenges. This research project is aimed at studying regional human capital development strategies of domestic areas to find out how regional institutions respond to the challenges of the global economy. The results of the given study can serve as the guidelines for the formation of domestic regional cluster networks aimed at improving the international competitiveness of the RFsubjects.

References

1. P. Belley, Understanding Wage Growth: Estimating and Testing Learning-by-Doing, *Journal of Human Capita*l **11**, 2, 213-246 (2017)
2. K. Angelopoulos, J. Malley, A. Philippopoulos, Human Capital Accumulation and Transition to Skilled Employment, *Journal of Human Capital* **11**, 1, 72-105 (2017)

3. N. Bontis, W. C. C. Keow, S. Richardson, Intellectual capital and business performance in Malaysian industries. *Journal of Intellectual Capital* **1**(1), 85–100 (2000)

4. M. Giorcelli, The long-term effects of management and technology transfers. *American Economic ReviewVolume* **109**, 121-152 (2019)

5. M. A. Youndt, *Human resource management system, intellectual capital and organizational performance.* Doctoral thesis. Pennsylvania State University (1998)

6. C. Chen, Construct model of knowledge-based economy indicators. *Journal of American Academy of Business* **13**(1), 215–222 (2008b)

7. *Global Human Capital Trends 2016 - The New Organization: Different by Design*, Deloitte University Press, 2016.

8. P. Oreopoulos, U. Petronijevic, Student coaching: How far can technology go? *Journal of Human Resources,* **53**, 2, 299-329 (2018)

9. T. Filippone, D. Youden, K. Pennington, P. Fersht, *Human Resources Transformation: Is It Driving Business Performance?* HfS Research (2012)

10. T. Good, C. Farley, H. Tambe, S. Cantrell, Trends Reshaping the Future of HR: Digital Radically Disrupts HR, *Accenture* (2015)

11. *Commission of the European Communities*. Building the knowledge society: Social and human capital interactions (2003).

12. S. McElhinney, Exposing the interests: Decoding the promise of the global knowledge society. *New Media & Society* **7**(6), 748–769 (2005)

13. A. Toffler, *The third wave* (Bantam Books, London, 1980)

14. M. Kuppusamy, B. Shanmugam, Information-communication technology and economic growth in Malaysia. *Review of Islamic Economics* **11**(2), 87–100 (2007)

15. J. Naisbitt, N. Naisbitt, D. Philips, *High tech high touch: Technology and our search for meaning* (Nicholas Brealey Publishing, London, 1999)

16. B. L. Castleman, F. X. Murphy, W. L. Skimmyhorn, Marching across Generations? Education Benefits and Intrahousehold Decision-Making, *Journal of Human Capital* **13**, 3, 410-433 (2019)

17. *Economist & IBM. E-readiness rankings.* Digital Economy Index (2010).

18. S. McElhinney, Exposing the interests: Decoding the promise of the global knowledge society. *New Media & Society* **7**(6), 748–769 (2005)

19. S. H. Bakry, A. Al-Ghamdi, A framework for the knowledge society ecosystem: A tool for development. In: *The Open Knowledge Society. A Computer Science and Information Systems Manifesto.* Springer, Heidelberg (2008)

20. I. Ehrlich, D. Li, Z. Liu, The Role of Entrepreneurial Human Capital as a Driver of Endogenous Economic Growth. *Journal of Human Capital* **11,** 3, 310-351 (2017)

21. D. Archibugi, A. Coco, Measuring technological capabilities at the country level: A survey and a menu for choice. *Research Policy* 34, 175–194 (2005)

22. *ITU*. World telecommunication/ICT development report (2010)

23. *Monitoring the development of the information society in the Russian Federation.* Available at: http://www.gks.ru/free_doc/new_site/figure/anketa1-4.html

Appendix 1

No	Subject of Russian Federation	No	Subject of Russian Federation
1	the Belgorod Region	43	the Stavropol Region
2	the Bryansk Region	44	the Republic of Bashkortostan
3	the Vladimir Region	45	the Republic of Mari El
4	the Voronezh Region	46	the Republic of Mordovia
5	the Ivanovo Region	47	the Republic of Tatarstan
6	the Kaluga Region	48	the Udmurt Republic
7	the Kostroma Region	49	the Chuvash Republic
8	the Kursk Region	50	the Perm Territory
9	the Lipetsk region	51	the Kirov Region
10	the Moscow region	52	The Nizhny Novgorod region
11	the Oryol Region	53	the Orenburg Region
12	the Ryazan region	54	the Penza Region
13	the Smolensk region	55	the Samara Region
14	the Tambov region	56	the Saratov Region
15	the Tver region	57	the Ulyanovsk Region
16	the Tula region	58	the Kurgan Region
17	the Yaroslavl region	59	the Sverdlovsk Region
18	the city of Moscow	60	the Khanty-Mansijsk Autonomous District
19	the Republic of Karelia	61	the Yamalo-Nenets Autonomous District
20	the Republic of Komi	62	the Tyumen Region (not Autonomous District)
21	the Arkhangelsk region	63	the Chelyabinsk Region
22	the Vologda region	64	the Republic of Altai
23	the Kaliningrad region	65	the Republic of Buryatia
24	the Leningrad region	66	the Republic of Tuva
25	the Murmansk region	67	the Republic of Khakassia
26	the Novgorod region	68	the Altai Territory
27	the Pskov region	69	the Zabaikalye Territory
28	the city of St. Petersburg	70	the Krasnoyarsk Region
29	the Adygeya republic	71	the Irkutsk Region
30	the Republic of Kalmykia	72	the Kemerovo Region
31	the Republic Of Crimea	73	the Novosibirsk Region
32	the Krasnodar region	74	the Omsk Region
33	the Astrakhan region	75	the Tomsk Region
34	the Volgograd region	76	the Republic of Sakha (Yakutia)
35	the Rostov region	77	the Kamchatka Region
36	the city of Sevastopol	78	the Primorye Territory
37	the Republic of Dagestan	79	the Khabarovsk Territory
38	the Ingush Republic	80	the Amur Region
39	the Kabardino-Balkar Republic	81	the Magadan Region
40	the Karachay-Cherkess Republic	82	the Sakhalin Region

41	the Republic Of North Ossetia-Alania	83	the Jewish Autonomous Region
42	the Republic Of Chechnya	84	the Chukotka Autonomous District