The Principles of Forming a Data-Driven University Model Within the Cluster-Network Model of Innovative Development

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Abstract The article is devoted to the problem of the formation of personnel competitive in the conditions of a post-industrial cluster-network model of innovative development. The authors develop an approach to constructing the cluster-network model based on new mechanisms for the collaboration of the Science, Industry and Government. The approach is implemented through the identification of the information, covering all the elements of the cluster-network model, significant for the analysis of human capital. An analysis of the prerequisites and the identification of conditions, criteria and methods that allow Universities to form personnel of a fundamentally new nature is performed. It made possible to develop a system of indicators for building a data-driven model describing the development of the University as the primary producer of human capital, in contrast to other participants in the collaboration being more the consumers of human resources. This gives opportunities and conditions for creating a data-driven educational environment management system for universities targeting at formatting human capital competitive in the new conditions.

Keywords Cluster-network model · Human capital · University · Data-driven system

1 Introduction

Social network communications, greatly increasing the speed and variety of exchanges, open up fundamentally wider opportunities for the development of the economy, society and human capital [1]. In the twenty-first century, economies with a single managing center can no longer cope with the growing massive online flows of economic information and are replaced by self-governing network systems built on horizontal connections and continuous approvals [2]. Such type of interactive

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E. Zaramenskikh and A. Fedorova (eds.), *Digitalization of Society, Economics and Management*, Lecture Notes in Information Systems and Organisation 53,
https://doi.org/10.1007/978-3-030-94252-6_17

network cooperation, called collaboration, is the main mechanism for the development of new economic systems, where network participants constantly exchange explicit and implicit knowledge, continuously reconcile decisions and coordinate actions [3]. New sources of growth emerge from the internal structural and balancing opportunities that arise in the course of collaboration. In this way, the formation of a Cluster-Network Model (CNM) of collective self-government is carried out, where ecosystems with a cluster structure acquire the ability of dynamic self-development without the participation of a hierarchical center. The main properties of the new model are its adaptability, emergence, development nonlinearity, self-organization and self-regulation, fractal repeatability and synergy [4].

Digital transformation, technology updates and global competition lead to the replacement of both hierarchical and market forms of interaction between economic entities with a new paradigm of network non-hierarchical order of interaction and cluster structure. The background for the changes were the diversification of production, nonlinear development of innovations, the emergence of a widespread online environment and multiform communication nodes around which global economic networks grow. The combination of these factors leads to the transformation of country and regional economies from a set of hierarchical structures into a complex system of cluster-network ecosystems that operate in the mode of collective creation and dissemination of innovations [5]. Note that the progressive development of integration and globalization processes is inevitably followed by a decline and a kind of rollback. Therefore, at certain stages of development, we can expect some weakening of the internationalization of the network economy, but the general vector of its development tends to grow [6].

Of all especially the regional clusters are the best basic structural units to meet the conditions of global digital reality [7]. The cluster is a complex adaptive system characterized by three analytical dimensions—special production agglomerations, special innovative ecosystems and special economic projects. Regional innovation clusters hold a central place among various types of business networks as new basic elements and a typical format for organizing production activities in the context of the transition of national economies to an innovative growth model. Of particular interest is the study of the dependence of the clusters' innovative capabilities on network synergistic effects arising from the collaboration of participants on the principles of a Triple Helix Model [8].

The phenomenon of the Triple Helix of University-Industry-Government relations, which first appeared in Silicon Valley, was later described as a special model of nonlinear and interactive collaboration—Triple Helix Model (THM), resembling linkages in a DNA chain. Collaboration of at least three functional different participants creates complex synergy and communication, which provides dynamic stability under conditions of uncertainty, allowing clusters to move to a higher level in self-development mode [9].

It is the University that begins to play a special role in the modern world, which becomes the center of inter-network relations at the national and supranational levels [10]. The University turns out to be the center of network connections and relations, often acting as their initiator within the framework of the classical model

of a network society, according to [11]. The university in this new capacity has to carry out many new functions that did not exist earlier or, at best, were secondary. Interacting in the triad of University-Industry-Government relations, even a State University begins to work in many ways like a production corporation, simultaneously performing social functions, while maintaining the main purpose of its existence—science and education. In this aspect, the example of the University clearly demonstrates the tendency of expansion and intersection of functions of various actors of the Triple Helix Model, characteristic of the modern world [12].

In modern conditions of digital transformation, the data-driven approach is implemented primarily in Business, Finance and Industry. Examples are presented by SAP, Sberbank, Yandex, ID Finance, PJSC Gazpromneft and many others. In the work [13] authors showed that "organizations using big data and analytics within their innovation processes are 36% more likely to beat their competitors in terms of revenue growth and operating efficiency". Work [14] describes the application of data-driven business models by start-up firms. In [15], the cases of implementing data-driven business models in different companies are presented, as well as the framework of such a model.

Examples of using a data-driven control system in a school are known in the literature [16, 17] introduced in the conceptual framework for Data-Driven Decision Making (DDDM) for school. Paper [18] discusses the principal-agent theory to identify strengths and diagnose problems in current DDDM plans and to help devise policy options for plans for future. An empirical study of principals' DDDM practices identified the factors influencing DDDM using the theoretical frame of information use environments was carried out in [19]. In most studies, the school is considered as a consumer of new environmental requirements. A different approach is required by the University, which not only explores the needs of the modern market, but is itself the driving force behind its development, owing to scientific and innovative potential [20, 21].

2 Model Description

This paper explores the interactions of four cluster members—Government, Industry, University and Professional Community (ProfCommunity), considered in a generalized sense (Fig. 1).

The aim of the study is to describe the prerequisites and conditions for creating a system for managing the educational environment, which will provide the University with the formation of personnel competitive in the modern conditions of a post-industrial economic development with new mechanisms for the collaboration of the Government, Industry, Science and the University.

The approach is implemented through the study of information relevant to the analysis of human capital related to all elements of the CNM, and the identification of conditions, criteria and methods for the formation of personnel of a fundamentally

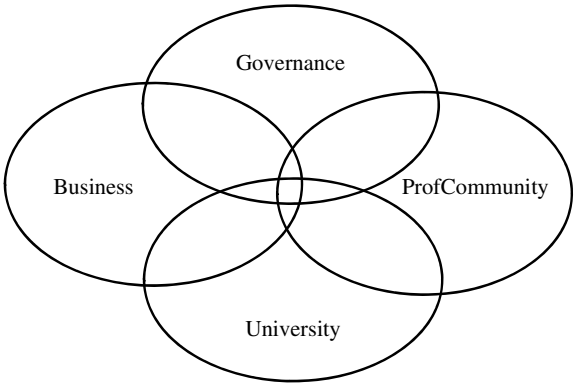

Fig. 1 Diagram of non-hierarchical network interaction of cluster members

new nature. It will allow developing a system of indicators for constructing a data-driven model for the development of the University as a major producer of human capital, unlike other participants in the collaboration, who are mainly consumers of human resources.

Since 2012, support for cluster initiatives has become a new instrument of Russian innovation policy. According to the results of the competitive selection, the "List of Pilot Programs for the Development of Innovative Territorial Clusters" included 25 cluster projects with high scientific and technical potential. Of these, 14 subsequently received the right to a state subsidy from the federal (33%), regional and local (14%) budgets, as well as from extra budgetary sources [22].

The effectiveness of cluster-network structures in Russia, depending on budgetary constraints, was studied in [23]. The typology of the regions and the system of indicators characterizing the regional cluster potential based on the assessment of the development of institutional sectors using the Triple Helix Model allowed the authors to identify four groups of regions with similar cluster potential indicators and draw conclusions about the prospects for regional innovative development (according to state statistics for 2013).

The work [24] presents a comparative analysis of the digital development of Russian regions based on open sources. Hierarchical clustering by standard indicators of state statistics (for 2014 and 2017) made it possible to identify four large groups of regions. The leading regions forming the first cluster (Moscow, Moscow obl., St. Petersburg, Tatarstan, Tyumen obl., Bashkortostan) can be compared in their level of digitalization with world leaders, while regions forming next two clusters are more comparable with the states of the Active Followers and Lagging Followers categories.

The system of indices developed in [23], based on an assessment of the development of institutions of power, science and business, which characterizes the cluster potential of a region, does not explicitly contain an index of digitalization. Nevertheless, all of the above-mentioned six leading regions are included in the group with the highest level of cluster potential identified in [23]. This is natural, since the level of digitalization of the region is both a necessary condition and a prerequisite for creating regional clusters.

An essential feature of the digitalization level indicator is that the digital disparity generated by the existing economic and social gap between the regions of Russia itself provides an opportunity to overcome it due to the fast and inexpensive scaling inherent in digital solutions and services. The issue of the comprehensive development of all Cluster-Network Model actors in order to level the economic and social disproportions of the regions requires additional research and the development of new approaches and methods.

One of the tasks of the national project "Science" of the Government of the Russian Federation for 2018–2024 [25] is to create a new form of networking in the form of a network of world-class Scientific and Educational Centers (SEC). In accordance with the Decree of the Government of the Russian Federation of April 30, 2019 [26], the first SECs in 2019 began operating in five pilot regions of the Russian Federation. In fact, they are developing within the framework of the Cluster-Network Model described above. The leaders of the Russian Academy of Sciences and the Ministry of Science and Higher Education emphasize the role of regional authorities, which should become active participants not only in the creation, but also in the functioning of world-class SEC, along with education sector and science. Industry and business representatives are also showing interest in this kind of regional collaboration.

Human capital in the Cluster-Network Model plays a key role due to the property of mixed globally local mobility, in contrast to globally circulating flows of financial and physical capitals, or social capital localized in a geographical area [27]. The predominant producer of human capital in this model is precisely the University, since its main goal—educational and scientific activity for training personnel, unlike other institutional structures. In this aspect, an urgent problem for the University is to develop new ways of forming human capital, effective in the modern conditions of the post-industrial economy with new mechanisms of cluster-network collaboration of the Government, Industry, Science and the Professional Community.

There are a number of original approaches to solving this problem. Some educational institutions, such as the French school of programming "Ecole 42" [28] and its Russian counterpart "School 21" [29], use only innovative methods—a problem-targeted approach to learning, the formation of the necessary skills through solving real problems, students' cooperation with each other and in active collaboration with employers.

Article 15 of the Federal Law "On Education in the Russian Federation" № 273-FZ, 29.12.2012 [30], provides a network form for students to master educational programs using the resources of several organizations, including foreign ones. It is positioned as the most promising area integrating science, education and industry in the field of personnel training. Student network-building activities in this sense are an important field of study for furthering understanding of academic collaboration and entrepreneurship.

Successful examples of the network approach are hybrid programs of the Novosibirsk State Technical University [31]. According to these programs, the Institute of Chemical Biophysics and Mathematics SB RAS provides a scientific and partially technological base for graduate departments. Another instance are industrial post-graduate studies at the MISIS National University of Science and Technology,

where the University provides the training unit, and industrial partners participate in research, certification and diploma protection.

Some papers focus on Ph.D. students' participation in network-building activities understood as collaboration, mobility and support for commercialization from the university. The results of large-scale surveys at different European universities show that the majority of Ph.D. students are engaged in collaborations with external organizations, although they are on average interested in commercialization [32–34].

At the same time, general approaches to building a model for creating an educational environment that would allow the University to become a driver of human capital development within the framework of the CNM (Cluster-Network Model) have not been developed. The main difficulty here is not in adapting some foreign innovative initiatives, but in improving the competitive environment, encouraging collaboration and changing monopolistic structures. The solution to this problem is possible through the use of a strategic data-driven approach based on the operational analysis of actual big data, information and knowledge.

The proposed model of the educational environment based on a data-driven approach describes multidirectional interactive THM-type collaboration in a cluster University–ProfCommunity–Industry–Government. On the one hand, it is the basis for the development of strategic reengineering higher education process taking into account the needs of other cluster members. On the other hand, it allows revealing the opportunities for competitive development of Universities as suppliers of human capital for all elements of the network. The data-driven approach is implemented through the identification of information relevant for the analysis of human capital relating to all four elements of a CNM with new functions and collaboration mechanisms. It allows forming personnel of a fundamentally new nature, competitive in the new conditions, and helps the University to become a driver of human capital development in the context of digital transformation. In the classical approach of Schultz [35], human capital is considered as the potential ability of a person or group of people to generate income both through their innate abilities and talents, and through their education and competencies.

Changing the business models of companies leads to a change in the requirements for personnel from Business and Industry. This leads to the emergence of new trends in the development of HR technologies, such as HR branding—positioning the employer in the market, HR Digital—the transition of recruiting to the digital environment (using predictive analytics, machine learning, and artificial intelligence), Design Thinking—cognitive recruitment [36]. Some companies create corporate universities and training platforms, drawing on the potential of traditional educational institutions in the process of network interaction to meet their needs for staff competencies as quickly as possible [37].

The University forms such important elements of human capital as knowledge, skills and motivation. At the same time, the motivation increase is carried out also through the formation of knowledge and skills that are in demand in the labor market. On the other hand, the University, having scientific and innovative potential, can form such knowledge and skills that can become a driver for the industry, economics and other areas of activity development. Under these conditions, the University can create

a system of knowledge formation by analyzing the needs of other elements of the Cluster-Network Model. Such a system will help to form knowledge that is not only in demand at the moment, but will also determine the development of the economy and other sectors included in the network model in the future.

The methodology of the data-driven approach suggests the possibility of combining several research methods without making an exclusive emphasis on qualitative or quantitative, the choice of a particular method is due to the nature of the available data.

For creating a data-driven system, it is necessary to determine the sources of data that characterize the interaction of elements in a CNM. Let us single out the attributes of CNM elements, which make it possible to analyze the current state and needs for human capital.

For Industry:

- Plans, goals, mission, values,
- strategy,
- technologies used,
- requirements for employees,
- company knowledge bases,
- corporate university programs.

For the Government:

- Government programs,
- development strategies,
- Federal State Educational Standards.

For Professional Community:

- Professional standards,
- Body of Knowledge, National standards and International standards,
- competency cards,
- research and practices,
- professional conferences.

For Universities:

- Curriculums,
- Educational Standards,
- course programs,
- educational technology,
- scientific capital,
- information technology,
- scientific events: academic conferences, workshops, discussion, etc.

The selected attributes are data sources for building a data-driven system. The allocation of significant information from the described sources by different methods, including semantic analysis, will make it possible to develop methods for analyzing

the needs for human capital at present and in the future for Industry and the Government, as well as investigate the compliance of professional standards and business needs.

The professional community creates its own Body of Knowledge (BOK) and Professional Standards for different professional spheres. The Standards most fully reflect the requirements and development trends in these professional areas. In the field of software engineering, this standard is SWEBOK, in the field of IT process management—ITIL, COBIT, IT4IT, etc., in the field of data management—DMBOK, in the field of business process management—BPMBOK, in the field of project management—PMBOK and PRINCE, in areas of business analytics—BABOK, etc. All Standards are verified and updated on the basis of needs declared by business and government agencies. On the other hand, fundamental breakthrough scientific research carried out by the scientific community and universities allows not only the expansion and addition of existing Bodies of Knowledge, but also the formation of new ones.

An Industry as a consumer of human capital generates a request for hard & soft skills and knowledge, formalizing it through job advertisements. The role of the University's interaction with Industry in this aspect is to identify the current needs in skills and knowledge and to form broader knowledge and motivation among graduates through a promising vision of the development trends of science, economy and society.

Thus, the creation of a data-driven system is possible through the solution of the following tasks:

- Creation of a system for collecting and analyzing documents that are attributes of four entities: Government, Industry, Professional Communities, University.
- Identification of relevant information in terms of human capital.
- Creation of an indicator system for matching competencies of university graduates with the existing needs of companies based on an analysis of requirements for employees in the labor market.
- Creation of an indicator system for matching the competencies of university graduates with the company needs prospects.
- Creation of a system of indicators (quantitative and qualitative) and methods for conducting strategic reengineering of higher education process.
- Application of methods for the quantitative assessment of the educational programs' semantic significance.

The developed system allows constructing a University profile in terms of interaction with other CNM institutions in the framework of the regional cluster. Figure 2 shows a schematic diagram for such a profile:

- The University interacts with three elements of the network structure—the interaction is carried out in both directions (the up arrow indicates the impact of the University on other elements; the down arrow indicates the impact them on the University).

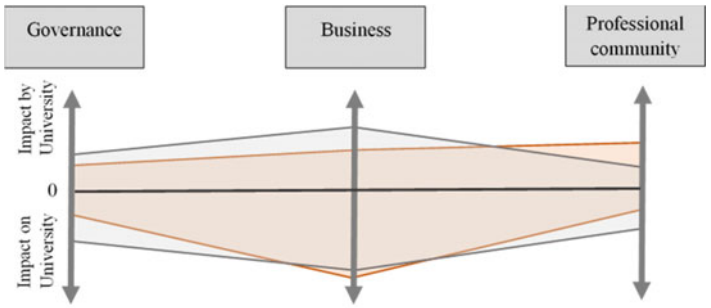

Fig. 2 A conceptual diagram for two universities portraits in the context of interaction with CNM elements within their cluster

- Each element of the network structure affects the formation of knowledge and skills—the University identifies the needs for human capital (the degree of impact is indicated by the distance from the zero level to the top line of the university profile).
- The University is influenced by the elements of the network structure—it forms the knowledge and skills that will be demanded in the future (the degree of impact is indicated by the distance from the zero level to the bottom line).

3 Conclusion

Digital transformation, technology upgrades and global competition determine the relevance of the national economies' transition to an innovative type of growth that is able to adapt the domestic economic environment to fundamental global changes. Digitalization and the widespread use of ICT give rise to the development of a new nonlinear, decentralized and interactive Cluster-Network Model of creating innovations. Both the creation of new ideas and knowledge and their transformation into innovations take place in the collective action mode of various institutional sectors, united on the Internet platforms into single ecosystems.

This gives opportunities and conditions for creating a data-driven educational environment management system for universities targeting at formatting human capital competitive in the new conditions. The goal is achieved through:

- Analysis of the interaction between the Government, Industry, Professional Community and the University based on a network model with horizontal connections. Each element of the network is viewed through a set of attributes related to human capital: needs, vision, prospects, etc.
- University positioning as a producer of human capital within the CNM.

The application of a data-driven approach to managing the educational environment for the formation of human capital by Universities will become one of the keys to the dynamic self-development of clusters without the participation of a hierarchical center.

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