OECONOMIA COPERNICANA

VOLUME 10 ISSUE 1 MARCH 2019

p-ISSN 2083-1277, e-ISSN 2353-1827

www.oeconomia.pl

ORIGINAL ARTICLE

Citation: Markhaichuk, M., & Zhuckovskaya, I. (2019). The spread of the regional intellectual capital: the case of the Russian Federation. *Oeconomia Copernicana*, *10*(1), 89–111. doi: 10.24136/oc.2019.005

Contact to corresponding author: m.marhaychuk@gmail.com; Vladimir State University named after Alexander and Nikolay Stoletovs, Gorky Street 87, 600000, Vladimir, Russian Federation

Received: 17.12.2018; Revised: 4.02.2019; Accepted: 13.02.2019; Published online: 27.02.2019

Maria Markhaichuk
Vladimir State University named after Alexander and Nikolay Stoletovs, Russia
orcid.org/0000-0003-3459-9229

Irina Zhuckovskaya
Vladimir State University named after Alexander and Nikolay Stoletovs, Russia
orcid.org/0000-0002-2824-0247

The spread of the regional intellectual capital: the case of the Russian Federation

JEL Classification: *O00; O34; R11*

Keywords: *regional intellectual capital; percolation; propagation*

Abstract

Research background: The positive relationship between the availability of intellectual capital and the ability of the state, region or firm to develop economically stimulates an increase in the intellectual capital. In order to manage intellectual capital, it is necessary to have a clear idea of its availability, capacity, features, growth reserves, as well as concentration in certain territories and ability to spread. Many studies are devoted to the measurement of intellectual capital, its diffusion and impact on the economic efficiency of the organization, region, and nation. However, in the case of the Russian Federation there is a gap in the study of the spread of intellectual capital over the country.
Purpose of the article: The purpose of the article is to evaluate intellectual capital in the federal districts of the Russian Federation and to model the spread of intellectual capital.
Methods: Data on 8 Russian federal districts for the 2017 year from Unified Inter-departmental Information and Statistical System (EMISS) of the Russian Federation were taken as a basis for the research. Based on three-component model (human capital, structural capital, and relational capital), we formed a set of indicators for assessing regional intellectual capital, relevant to the Russian Federation. This allowed us to evaluate the integrated indicators of intellectual capital in federal districts and to determine the probability of intellectual capital spreading from each feder-

al district to neighboring federal districts. We used percolation theory methods to model the spread of intellectual capital.
Findings & Value added: The study contributes to the Russian regional knowledge on intellectual capital. Intellectual capital in the Russian Federation is disproportionately distributed, concentrating closer to the capital, and has a lower level in remote territories. It spreads unevenly, flowing from the Central Federal District to neighboring federal districts, however, other federal districts develop almost in isolation.

Introduction

In the modern world, intellectual capital (IC) has become one of the most valuable assets of an organization, region or state. IC was defined as "organized knowledge that can be used to produce wealth" (Demigha, 2015, pp. 213–221). From a wholly accounting approach, it has been scanned and reported as intangible assets, source in itself of sometimes abnormal expected future returns (Lopes, 2014, pp. 91–98).

Like any other form of capital, IC has an impact on the areas of life it interacts with. Its functioning and development lead to a chain reaction in adjacent areas, and serve as an impetus to its emerging and growth in functioning units it comes into contact with.

The importance for the Russian Federation of researching issues related to IC is confirmed by the fact that Russia cooperates with the OECD on statistical issues in the context of the current work of the OECD in the field of science, technology and innovation. One of the tasks of the Committee on Industry, Innovation and Entrepreneurship in the framework of the implementation of the Plan of Cooperation between Russia and the OECD for 2017–2018 years in the field of scientific and technical information is participation in research projects on the influence of various aspects (technology, innovation, intellectual capital) on the formation of global value chains.

The literature on IC is quite vast. Nevertheless, concerning empirical studies, the total number is considerably less, especially for the Russian Federation. The difficulty with gathering data about any one of the analysis axes and in various contexts can be one explanation for the limited number of empirical studies. Another reason for the low number of empirical studies could lie in the diversity of components and the multiplicity of indicators measuring IC, whether in the organizational, regional or national context (Pedro *et al.*, 2018, pp. 407–452).

Many studies are devoted to the assessment of IC level, its impact on the economic efficiency of the organization, region, and nation (Buenechea-Elberdin, 2017, pp. 262–285; Demigha, 2015, pp. 213–221; Trequattrini *et al.*, 2018, pp. 199–211).

There are studies on the measurement of regional IC (Nitkiewicz *et al.*, 2014, pp. 246–257; Medina *et al.*, 2007, pp. 473–487; Trequattrini *et al.*, 2018, pp. 199–211), including regional IC in the Russian Federation (Kireeva & Galiakhmetov, 2015, pp. 240–247; Kotenkova & Korablev, 2014, pp. 342–348, Tsertseil & Ordov, 2017, pp. 416–424). There is a wide range of both theoretical and empirical literature devoted to knowledge diffusion (Autant-Bernard *et al.*, 2013, pp. 196–210; Kaneva & Untura, 2017, pp. 133–159; Golichenko & Malkova, 2017, pp. 1133–1145). However, in general, in all federal districts of the Russian Federation IC has not been estimated and the spread of IC has not been studied.

This paper aims to analyze the spread of intellectual capital in the federal districts of the Russian Federation.

Our paper is structured as follows: firstly, we analyze the literature on IC assessment and its diffusion modeling. Secondly, we describe the methodology for assessing intellectual capital in the Russian Federation's federal districts, which is based on Stam and Andriessen (2009) two-layer IC monitor, as well as the methodology for modeling IC spread in the federal districts of the Russian Federation using percolation theory. Finally, we present the results of the conducted assessment and modeling, based on the data on 8 Russian federal districts for the 2017 year from Unified Interdepartmental Information and Statistical System (EMISS) of the Russian Federation, discuss them, give recommendations and draw conclusions.

Literature review

IC is formed of intangible assets, also called intangible resources, intellectual resources, or resources and capacities based on knowledge, among others, which combined with tangible capital contribute to producing value added for organizations/regions/nations (Pedro *et al.*, 2018, pp. 407–452).

The existing literature presents different approaches to the measurement of IC. Approaches vary depending on viewpoints of different groups of interest or disciplines. In addition, there are different approaches to the measurement of each dimension of IC.

The most popular is the three-component model of IC (human capital, structural capital and relational capital) and its variations, which include such components as technology and IT capital (Buenechea-Elberdin, 2017, pp. 262–285; Matricano, 2016, pp. 654–674; Pedro *et al.*, 2018, pp. 407–452; Stam & Andriessen, 2009, pp. 442–451; Wee & Chua, 2016, pp. 414–438).

In a learning region the most important intangible resources are represented by the local IC (Stewart, 1997, p. 104). In this context, entrepreneurial universities can assume a critical role to foster the enhancement of all the three components of local IC and are able to affect it in different phases and ways related to the inception and development of firms (Trequattrini *et al.*, 2018, pp. 199–211).

The set of components for evaluating IC varies from study to study. It essentially depends on the local characteristics of the territories. For example, to assess the IC of small territory (island of Gran Canaria, Spain), Medina *et al.* (2007, pp. 473–487) developed a model based on the method of expert assessments. The model comprises tourism capital, economic activity capital, social capital, environmental capital, public administration capital, training and development capital, and result capital. This is not the traditional division of IC.

Wide recent literature provides evidence which suggests that the economic performance across regions differs not only in traditional factor endowments (labor and physical capital), but also mainly in technological, human and social capital (Dettori *et al.*, 2012, pp. 1401–1416). A large part of total factor productivity differences across the European regions is explained by disparities in the endowments of these intangible assets (Stam & Andriessen, 2009, pp. 442–451).

Part of the studies on the evaluation of IC is based on the methods of expert assessments. Due to the lack of official data for the evaluation of IC, expert assessment methods may be the only possible option in some cases. However, such assessments of IC are subjective, highly dependent on the competence of experts.

One of the non-expert regional intellectual capital (RIC) assessment methods is Data Envelopment Analysis (DEA). Nitkiewicz *et al.* (2014, pp. 246–257) used DEA for knowledge asset evaluation that enables the understanding of cause and effect relationships between IC, academic sector performance, and regional economic growth.

Stam and Andriessen (2009, pp. 442–451) proposed a detailed and convenient methodology for evaluating IC. Based on the taxonomy of three, they developed a monitor for the measurement of IC. Within this monitor, they added a second layer of classification (assets, investments, effects).

This methodology and the indicators it includes are designed for the national level, therefore, in its present form it is not suitable for the purposes of our study, which is aimed at assessing regional IC. However, the approach to IC evaluation allows evaluating IC based only on objective indicators and eliminates the subjectivity of assessment. In addition, it provides an opportunity to conduct research in two dimensions, since it is based on two layers of IC classification.

There is vast literature on knowledge diffusion and spillovers at the regional level. Autant-Bernard *et al.* (2013, pp. 196–210) based on the results of the empirical literature devoted to localized knowledge spillovers highlight some policy implications within European regions. Bretschger (1999, pp. 251–268) analyzed scale effects as well as resource relocation effects of intra- and interregional knowledge diffusion. Caragliu and Nijkamp (2016, pp. 749–774) examined which types of proximity enhance or hamper knowledge flows, and whether local absorptive capacity favor such flows.

Some studies use patent data to study knowledge diffusion. Bottazzi and Peri (2003, pp. 687–710) found that doubling R&D spending in a region would increase the output of new ideas in other regions within 300 Km only by 2–3%, while it would increase the innovation of the region itself by 80–90%. Singh (2005, pp. 756–770) measured knowledge flows using patent citation data. Intraregional and intrafirm knowledge flows are found to be stronger than those across regional or firm boundaries.

Spatial knowledge diffusion through research and collaborative networks was also the subject of research. Autant-Bernard *et al.* (2007, pp. 341–350) pointed out the necessity to take into account the increasing importance of collaboration networks in the process of knowledge diffusion and to assess better their consequences in terms of the geographical distribution of innovation and growth. Cassi *et al.* (2008, pp. 283–293) evaluated the structure of collaborative networks and of knowledge transfer between research, innovation and deployment activities in the field of information and communication technology for the European Union as a whole and for several European regions. They found that research networks complement diffusion networks by increasing the number of links and organizations involved in exchanging knowledge. Miguelez and Moreno (2013, pp. 321–354) assessed the role played by inventors' cross-regional mobility and collaborations in fostering knowledge diffusion across regions and subsequent innovation.

As for the Russian Federation, regression results of Kaneva and Untura (2017, pp. 133–159) demonstrate that spillovers of expenditure on technological innovation are associated with a greater economic growth. Gunther and Meissner (2017, pp. 499–512) investigated if knowledge diffusion channels function more effective and efficient in organically grown self-organized channels or if targeted public policy intervention is needed to enhance these channels by means of attached cluster management. Golichenko and Malkova (2017, pp. 1133–1145) estimated the scale of diffusion of basic knowledge by the count of citations of the articles of considered journals files to literature sources which institutional address belongs to examined object. The study showed that Russia is the net exporter of knowledge. Also, as for Russia, the basic indicators of input and output parameters of the system of new knowledge production are lower in comparison with North America, Western Europe, Eastern Europe, Chine, Asia, and Pacific Region. Golichenko and Samovoleva (2015, pp. 223–230) considered the models of technology diffusion to determine the possible ways of balancing positive and negative externalities of international competition on the investment stage of the country development. Much of the attention of the study focuses on such an externality as a technological spillover.

Literature analysis showed that there are studies on some components of IC spillover in the Russian Federation, but the spread of overall IC was not modeled and studied yet.

Modeling methodology of IC spread in the federal districts of the Russian Federation

Percolation theory, the foundations of which were laid in Broadbent and Hammerslay (1957, pp. 629–641), is actively and successfully used for modeling of economic processes. It found its application in the study of information diffusion in financial markets (Andrei & Cujean, 2017, pp. 617–645), percolation of information through large and segmented markets (Duffie *et al*., 2014, pp. 1–32; Duffie & Manso, 2007, pp. 203–209), privacy-constrained network formation (Acemoglu *et al.*, 2017, pp. 255–275), distress propagation in a financial system represented as a large network (Amini *et al.*, 2016, pp. 329–365), percolation of information in dark markets (Asparouhova & Bossaerts, 2017, pp. 518–544), delayed takeoff in new-product diffusion (Hohnisch *et al*., 2008, pp. 1001–1017), innovation percolation in complex technology spaces (Silverberg & Verspagen, 2005, pp. 225–244).

Since the percolation theory has found such wide application in the study of economic processes, we have attempted to model the spread of IC on the examples of federal districts of the Russian Federation using percolation theory.

The phenomenon of IC propagation is determined by:

- the environment in which the spread of IC is observed. The order in the search for new knowledge, multilateral systematic assessment of options for the use of the resulting IC, regulating the activities of authorities at all levels are distinctive features of this environment in the modern

world. The IC propagation medium can be represented as a percolation lattice consisting of identical rectangular cells;
- the external source that provides percolation in the medium of IC propagation. IC and the activities of the owners of IC, seeking to commercialize the results, are this source;
- percolation method of the medium, which depends on an external source. The system of dissemination of knowledge and information in the modern world determines the method of percolation.

In this case, it is possible to propose IC percolation model in a two-dimensional square lattice consisting of nodes (we will take IC consumption centers as nodes), which may be susceptible or not susceptible to IC.

IC consumption centers are subjects (individuals and legal entities) of intellectual (1), innovative (2), scientific (3) and managerial (4) activities.

1. Authors, inventors, etc.
2. Innovators and investors. Innovators can be research organizations, universities, small innovative enterprises, engineering companies, R&D departments at large enterprises, individual inventors, design centers, technoparks, technopolises (science cities), business incubators, innovative firms, concerns and corporations, financial and industrial groups. Investors are state and commercial banks, investment and insurance companies, pension funds, venture funds, specialized companies, individuals.
3. Individuals and legal entities whose constituent documents provide for scientific and/or scientific and technical activities (scientists, scientific organizations, etc.).
4. Organizations of various forms of ownership.

At the initial moment of time, all nodes of the lattice are unreceptive, and the task of the whole society, state structures, and business is to increase this susceptibility. Over time, as the source's activity and society's demand for IC grows, the number of conductive nodes gradually grows, and IC spreads evenly (or unevenly). This fully agrees with the second stage of the life cycle of any innovation — diffusion of innovations or IC into various spheres and branches of human activity. IC consumption centers are replaced randomly, the choice of any of the nodes for substitution is equally probable for the entire surface of the lattice.

As a rule, IC propagates gradually and, as a result, percolation occurs, i.e. the moment of appearance of such a state of the lattice, at which there exists at least one continuous path through adjacent conductive nodes from one to the other opposite edge of the lattice. Obviously, with an increase in the number of conductive nodes, this moment will come sooner.

If percolation occurs, it means that IC propagates beyond the region. If not, IC develops within the region and has no significant impact on other regions.

In order to simulate IC propagation in a two-dimensional lattice, it is necessary to determine the probability with which IC propagates between the lattice nodes.

The integral indicator characterizing the level of IC in the federal district displays the probability of IC spread.

In order to assess the likelihood of IC propagation, we have formed a set of indicators characterizing the IC of federal districts of the Russian Federation.

Data on 8 Russian federal districts for the 2017 year from Unified Interdepartmental Information and Statistical System (EMISS) of the Russian Federation were taken as a basis for the research.

We took a three-component model as a basis: human capital, structural capital and relational capital. Based on Stam and Andriessen (2009, pp. 442–451) monitor for the measurement of IC, which includes two layers of classification, we formed our own monitor for evaluation RIC. Each of the three types of IC is estimated from three different perspectives in order to stress the importance and differences between past, present and future developments: assets (present), investments (future), effects (past). The indicators of Stam & Andriessen monitor are intended for evaluation of national intellectual capital (NIC), therefore, we proposed indicators for evaluation of RIC, relevant in the Russian Federation.

We should note that the formation of indicators list for assessing IC at the level of federal districts has its own specifics. For example, the statistics service of the Russian Federation presents some important indicators only for the state as a whole, but not in the context of federal districts, therefore such indicators were not included in the assessment of IC in the context of federal districts of the Russian Federation. In general, the statistical information on the development of IC collected in the Russian Federation limits the possibilities for conducting research in this area. The resulting set of indicators for assessing IC is in Table 1.

Normalized IC indicators are calculated as follows:

$$y_i(x_i) = \frac{x_i - x_{min}}{x_{max} - x_{min}} \tag{1}$$

where:
y_i – normalized IC indicator,
x_i – IC indicator,
x_{min} – minimum value of IC indicator among federal districts,
x_{max} – maximum value of IC indicator among federal districts.

Human capital, structural capital, relational capital, overall indicator for IC, investments indicator, assets indicator and effects indicator evaluation formulas are given in Table 2.

After evaluating IC, the next step was to model the spread of IC.

We considered the simulation of IC spread on a grid with square cells. This grid is convenient to represent a two-dimensional array. For square lattice $L \times L$ the number of cells is $N = L^2$. In numerical modeling, the probability of percolation is estimated, which is determined by the expression:

$$P_\infty(p) = \lim_{N\to\infty} P_N(p). \quad (2)$$

No less important is the concept of "threshold of IC percolation". In the case of flow from node to node on a square lattice, the critical probability p_c at which a cluster appears for the first time, extending over the entire lattice, is 0.59275 ± 0.0003 (Ziff, 1986, pp. 545–548).

We simulated IC propagation on a grid of 50×50 cells using the Wolfram Mathematica package.

Cells can be in two states: "empty" or "busy". Each cell is filled with a certain probability p regardless of the state of its neighbors. In this model, we define the cluster as a group of occupied lattice cells associated with the nearest neighbors on the side of the cell. Thus, any two occupied cells belong to the same cluster, if it is possible to pass from one to the other cell through the occupied cells. Looking through all the cells in succession, we filled them with a probability p = 0.2. After performing these steps, we obtained the figure (Figure 1).

White color shows the medium of IC propagation; black color shows the cells in which IC has spread. As can be seen from the figure, the percolation did not occur, because the percolation cluster was not formed. A percolation (connecting) cluster is a cluster that connects one side of the considered area to another.

As the number of nodes perceiving and contributing to the propagation of IC increases, such a critical moment comes when percolation occurs, that is, IC propagates in a greater number of subjects of intellectual, innovative, scientific, and management activities. In an infinite system, the idea of a clearly defined percolation threshold, which does not depend on the sequence of random values that was used in the model experiment, is valid.

Figure 2 shows the case when percolation occurred, which means IC spread from the investigated region to the neighboring regions.

Results

The IC assessment carried out gave the following results for the federal districts of the Russian Federation in 2017 (Table 3–4, Figure 3).

Concerning the IC level, the leader is the Central Federal District. This is the federal district, which includes the Moscow region and the Russian capital city Moscow. The Central Federal District is the most populous. It accounts for the largest share of domestic spending on research and development, investment in intellectual property. It concentrates a significant part of foreign investment. The Central Federal District has the greatest human capital, and is the center of attraction of highly skilled labor. The Central Federal District bypassed the rest of the federal districts in terms of human capital, structural and relational capital.

However, there are indicators according to which the Central Federal District is not a leader. The Central Federal District has lower costs for environmental innovation than the Siberia Federal District. There may be several reasons for this. Firstly, the Siberia Federal District has a large number of industrial enterprises. Secondly, since innovations reach the capital more quickly, the Central Federal District industrial enterprises have already introduced environmental innovations earlier, and now do not need such large investments as enterprises of the Siberia Federal District.

Another indicator by which the Central Federal District does not lead in the Russian Federation is the share of the employed population aged from 25 to 65 years, who passed advanced training and (or) professional training in the total number of employed population of this age group. This is because the Central Federal District is the center of attraction of highly skilled labor. The Central Federal District has the best staff in the country, who do not need additional training.

The Northwest Federal District is superior to the Central Federal District in terms of the number of export agreements. This fact also has a logical explanation. In the Northwest Federal District is the majority of seaports of the Russian Federation, which was the reason for the conclusion of export agreements. In addition, the Northwest Federal District is a leader in the growth of high-performance jobs. As we have already noted, the Central Federal District has the best staff of the country. As for the Northwest Federal District, it includes the Northern capital of the Russian Federation — the city of St. Petersburg. This is the second city after Moscow in the number of highly qualified specialists.

In terms of GRP per capita, the Central Federal District lags behind the Ural Federal District. This is due to the fact that the population of the Central Federal District is three times greater than the population of the Ural Federal District (table 5), and the concentration of industrial enterprises in the Ural Federal District is high.

South Federal District leads in labor productivity index. This is because after the annexation of the Crimea the construction of infrastructure goes at an accelerated pace in the South Federal District.

Volga Federal District overtook other federal districts in technology export receipts under agreements with foreign countries. This is mainly due to the activities of the AvtoVAZ automobile company, which is the largest car manufacturer in Russia and Eastern Europe. Since 2014, the effective share of the Renault-Nissan alliance in the assets of AvtoVAZ has exceeded 50%. Since the beginning of 2017, Renault has begun to consolidate AvtoVAZ's indicators, and now the Russian market has become the second largest for Renault after France.

The analysis of the federal districts' IC in the context of the second layer of IC classification is of interest. Here again, we can single out the undisputed leader in terms of investment and the availability of assets. It is the Central Federal District. However, this federal district invests more than it gets. The return on investment in IC of the Northwest Federal District is superior to the rest of the federal districts. It follows that in this federal district IC is used more effectively. South, North Caucasus, Volga, Far East federal districts also achieved greater effects than they spent on them.

Then we made a simulation of IC propagation for the federal districts of the Russian Federation (Figure 4). Since in the studied federal districts the obtained IC propagation probabilities (0.85, 0.49, 0.23, 0.08, 0.41, 0.29, 0.26, 0.16) do not fall into the empirical confidence interval of the percolation threshold ($p_c = 0.59275 \pm 0.0003$), we can conclude about the propagation or non-propagation of IC to other regions on the basis of the obtained results.

As can be seen from the simulation results, the percolation cluster was formed only in the Central Federal District. From which it follows that IC is well spread only in the Central Federal District. Northwest and Volga federal districts are close to the percolation threshold.

Since the percolation threshold is a probability value of $p = 0.59$, then from one edge of the lattice to the other, IC is spread only in the Central Federal District. This means that IC flows from the Central Federal District to neighboring federal districts, however, other federal districts develop in isolation and their IC is not developed enough to have a significant impact on IC of other federal districts. This may indicate insufficient spread of IC and the need for management decisions aimed at increasing the estimates of factors affecting the value of IC spread probability.

Discussion and recommendations

Our research results are consistent with Kaneva and Untura (2017, pp. 133–159), who proved that regions that are geographically closer to other regions with high levels of expenditure on technological innovation tend to grow faster than regions surrounded by entities with low levels of expenditure on technological innovation. According to our research results, federal districts that coexist with federal districts with large IC, spread IC more strongly than federal districts adjacent to federal districts that have less IC. However, our findings are not consistent with the statement by Kaneva and Untura (2017, pp. 133–159) that spillovers of expenditure on technological innovation are associated with a greater economic growth. Our study showed that the Central Federal District, IC of which spreads more strongly than that of other federal districts, spends more than it gets. At the same time, other federal districts achieve greater economic growth at lower costs and less spread of IC.

Pedro *et al.* (2018, pp. 407–452) argued that human capital is observed not to be the most relevant in RIC and NIC, unlike the case in OIC. Our research in the contrary proved the relevance of human capital in RIC. In the case of the Russian Federation human capital has a higher level on average in the Russian Federation compared to other components of IC (average HC=0.13, average SC=0.11, average RC=0.11), so it can serve as the basis for further growth and spread of IC.

The results obtained confirm the observations on Bretschger (1999, pp. 251–268), who proved that increasing knowledge has a decreasing marginal return on income of the home region. However, his conclusion is about the knowledge, which stems from other regions, while our results showed decreasing return in the home region on the example of the Central Federal District, which demonstrated the strongest spillover of knowledge in the Russian Federation.

We should agree with Kotenkova and Korablev (2014, pp. 342–348), who studying RIC of the Russian Federation concluded, that socioeconomic differentiation is a great obstruction for innovation economics which is forming in Russia. That’s why it is very important to pay a special attention to the balanced development of intellectual capital in regions.

Obviously, there is a need to develop territories of the Russian Federation that are remote from the Central Federal District. The Russian Federation is already taking some steps in this direction. State programs and Federal target programs for the development of remote territories with innovative potential have been developed and are being implemented.

It is necessary to develop public-private partnership. In the context of the budget deficit, this will solve the problem of attracting funds for the implementation of basic functions for the development or creation of infrastructure.

At the state level, it is essential to develop Federal target programs for the creation of research territories. One example of such territories is the Skolkovo Innovation Center. This is a modern scientific and technological innovation complex under construction in Moscow for the development and commercialization of new technologies, being built “from scratch” science city, as well as the territory (a separate site), which is a city district of Moscow. The result of the activities of the Skolkovo Innovation Center should become self-governing and self-sustaining ecosystem favorable to the development of entrepreneurship and research that contribute to the creation of companies successful on the global market.

It is necessary to create business-state-education partnerships on the basis of regional universities, and co-finance intellectual development of enterprises.

There is a need to increase the interest of domestic business in the introduction of domestic patented inventions into production.

Regions should be supported at the state level. Support for young scientific personnel should be carried out at two levels. There should be support from the regions in providing housing or co-financing mortgages. There should be job guarantees at the federal level, the allocation of special jobs for young scientific personnel.

Conclusions

The paper is devoted to the analysis of IC spread in federal districts of the Russian Federation. The main findings of the study are:

– IC in the Russian Federation is disproportionately distributed, concentrating closer to the capital and has a lower level in remote territories.
– IC of the federal districts of the Russian Federation spreads unevenly. It flows from the Central Federal District to neighboring federal districts, however, other federal districts develop almost in isolation and their IC spread is not strong enough to have significant impact on development of other federal districts. This may indicate the need for management

decisions aimed at increasing the estimates of indicators affecting the value of IC spread probability.

– In the conditions of the Russian Federation the strongest spread of intellectual capital in the region does not guarantee high return on investments in IC.
– The federal districts that coexist with federal districts with large IC, spread IC more strongly than federal districts adjacent to federal districts that have less IC.
– The main activities that will contribute to the development of IC in the regions of the Russian Federation are: the development of public-private partnerships, the development of remote territories of the Russian Federation, the development at the state level of target programs for the creation of research territories, the creation of business-state-education partnerships on the basis of regional universities, co-financing of intellectual developments for enterprises, support for young scientists at the regional and the federal level.

The state regional governments can use the results of the study to identify problems and opportunities for innovative development of regions and to elaborate measures for IC elements' improvement in the framework of the regional development strategy.

Further research prospects lie in the direction of studying the impact of individual IC indicators growth on the spread of IC.

References

Acemoglu, D., Makhdoumi, A., Malekian, A., & Ozdaglar, A. (2017). Privacy-constrained network formation. *Games and Economic Behavior, 105*(C). doi: 10.1016/j.geb.2017.08.001.

Amini, H., Cont, R., & Minca, A. (2016). Resilience to contagion in financial networks. *Mathematical Finance, 26*(2). doi: 10.1111/mafi.12051.

Andrei, D., & Cujean, J. (2017). Information percolation, momentum and reversal. *Journal of Financial Economics, 123*(3). doi: 10.1016/j.jfineco.2016.05.012.

Asparouhova, E., & Bossaerts, P. (2017). Experiments on percolation of information in dark markets. *Economic Journal, 127*(605). doi: 10.1111 /ecoj.12464.

Autant-Bernard, C., Fadairo, M., & Massard, N. (2013). Knowledge diffusion and innovation policies within the European regions: challenges based on recent empirical evidence. *Research Policy, 42*(1). doi: 10.1016/j.respol.2012.07.009.

Autant-Bernard, C., Mairesse, J., & Massard, N. (2007). Spatial knowledge diffusion through collaborative networks. *Papers in Regional Science, 86*(3). doi: 10.1111/j.1435-5957.2007.00134.x.

Bottazzi, L., & Peri, G. (2003). Innovation and spillovers in regions: evidence from European patent data. *European economic review, 47*(4). doi: 10.1016/S0014-2921(02)00307-0.

Bretschger, L. (1999). Knowledge diffusion and the development of regions. *Annals of Regional Science, 33*(3). doi: 10.1007/s001680050104.

Broadbent, S. R., & Hammerslay, J. M. (1957). Percolation process. I. Crystals and mazes. *Mathematical Proceedings of the Cambridge Philosophical Society, 53*(3).

Buenechea-Elberdin, M. (2017). Structured literature review about intellectual capital and innovation. *Journal of Intellectual Capital, 18*(2). doi: 10.1108/jic-07-2016-0069.

Caragliu, A., & Nijkamp, P. (2016). Space and knowledge spillovers in European regions: the impact of different forms of proximity on spatial knowledge diffusion. *Journal of Economic Geography, 16*(3). doi: 10.1093/jeg/lbv042.

Cassi, L., Corrocher, N., Malerba, F., & Vonortas, N. (2008). The impact of EU-funded research networks on knowledge diffusion at the regional level. *Research Evaluation, 17*(4). doi: 10.3152/095820208x364535.

Demigha, S. (2015). Knowledge management and intellectual capital in an enterprise information system. In M. Massaro & A. Garlatti (Eds.). *Proceedings of the 16th European conference on knowledge management*. Reading: Academic Conferences Limited.

Dettori, B., Marrocu, E., & Paci, R. (2012). Total factor productivity, intangible assets and spatial dependence in the European regions. *Regional Studies, 46*(10). doi: 10.1080/00343404.2010.529288.

Duffie, D., Malamud, S., & Manso, G. (2014). Information percolation in segmented markets. *Journal of Economic Theory, 153*(C). doi: 10.1016/j.jet.2014.05.006.

Duffie, D., & Manso, G. (2007). Information percolation in large markets. *American Economic Review, 97*(2). doi: 10.1257/aer.97.2.203.

EMISS (2018). *State Statistics*. Retrieved form: http://fedstat.ru/ (01.10.2018).

Golichenko, O. G., & Malkova, A. A. (2017). The analysis of processes of new knowledge production in key world regions and Russia. *Journal of the Knowledge Economy, 8*(4). doi: 10.1007/s13132-016-0424-2.

Golichenko, O., & Samovoleva, S. (2015). The balance of externalities and internal effects in national innovation systems. In *10th European conference on innovation and entrepreneurship (ECIE)*. Reading: Academic Conferences Limited.

Gunther, J., & Meissner, D. (2017). Clusters as innovative melting pots? – the meaning of cluster management for knowledge diffusion in clusters. *Journal of the Knowledge Economy, 8*(2). doi: 10.1007/s13132-017-0467-z.

Hohnisch, M., Pittnauer, S., & Stauffer, D. (2008). A percolation-based model explaining delayed takeoff in new-product diffusion. *Industrial and Corporate Change, 17*(5). doi: 10.1093/icc/dtn031.

Kaneva, M., & Untura, G. (2017). Innovation indicators and regional growth in Russia. *Economic Change and Restructuring, 50*(2). doi: 10.1007/s10644-016-9184-z.

Kireeva, V., & Galiakhmetov, L. (2015). The assessment of the intellectual capital as a factor of investment attractiveness of the region. *Procedia Economics and Finance, 27*. doi: 10.1016/s2212-5671(15)00997-1.

Kotenkova, S., & Korablev, M. (2014). Evaluation of intellectual capital in regions of Volga Federal District of Russian Federation. *Procedia Economics and Finance, 14*. doi: 10.1016/s2212-5671(14)00722-9.

Lopes, I. T. (2014). The drivers of intellectual capital in an agriculture, cattle and forest farmstead. In D. Caganova & M. Cambal (Eds.). *Proceedings of the 6th European conference on intellectual capital*. Reading: Academic Conferences Limited.

Matricano, D. (2016). The impact of intellectual capital on start-up expectations. *Journal of Intellectual Capital, 17*(4). doi: 10.1108/jic-04-2016-0040.

Medina, A. J. S., Gonzalez, A. M., & Falcon, J. M. G. (2007). Intellectual capital and sustainable development on islands: an application to the case of Gran Canaria. *Regional Studies, 41*(4). doi: 10.1080/00343400600928327.

Miguelez, E., & Moreno, R. (2013). Do labour mobility and technological collaborations foster geographical knowledge diffusion? The case of European regions. *Growth and Change, 44*(2). doi: 10.1111/grow.12008.

Nitkiewicz, T., Pachura, P., & Reid, N. (2014). An appraisal of regional intellectual capital performance using Data Envelopment Analysis. *Applied Geography, 53*. doi: 10.1016/j.apgeog.2014.06.011.

Pedro, E., Leitao, J., & Alves, H. (2018). Intellectual capital and performance: taxonomy of components and multi-dimensional analysis axes. *Journal of Intellectual Capital, 19*(2). doi: 10.1108/jic-11-2016-0118.

Population of the Russian Federation by sex and age (2018). *Federal State Statistics Service*. Retrieved form http://www.gks.ru/wps/wcm/connect /rosstat_main/rosstat/ru/statistics/publications/catalog/doc_1140095700094 (01.10.2018).

Silverberg, G., & Verspagen, B. (2005). A percolation model of innovation in complex technology spaces. *Journal of Economic Dynamics & Control, 29*(1-2). doi: 10.1016/j.jedc.2003.05.005.

Singh, J. (2005). Collaborative networks as determinants of knowledge diffusion patterns. *Management Science, 51*(5). doi: 10.1287/mnsc.1040.0349.

Stam, C., & Andriessen, D. (2009). Intellectual capital of the European Union 2008. In *Proceedings of the European conference on intellectual capital*. Reading: Academic Conferences Limited.

Stewart, T. A. (1997). Brain power – who owns it ... how they profit from it. *Fortune, 135*(5).

Trequattrini, R., Lombardi, R., Lardo, A., & Cuozzo, B. (2018). The impact of entrepreneurial universities on regional growth: a local intellectual capital perspective. *Journal of the Knowledge Economy, 9*(1). doi: 10.1007/s13132-015-0334-8.

Tsertseil, J., & Ordov, K. (2017). The role of intellectual capital in the development of the regional cluster. *International Journal of Organizational Leadership, 6*(3), 416-424. doi: 10.19236/ijol.2017.03.09.

Wee, J. C. N., & Chua, A. Y. K. (2016). The communication of intellectual capital: the “whys” and “whats”. *Journal of Intellectual Capital, 17*(3). doi: 10.1108/jic-01-2016-0007.

Ziff R. M. (1986). Test of scaling exponents for percolation-cluster perimeters. *Physical Review Letters, 56*(6).

Annex

Table 1. Intellectual capital indicators

	Human capital	Structural capital	Relational capital
Investments	HCI_1: Funding of higher education institutions	SCI_1: Domestic costs of R&D SCI_2: Investments of organizations in technological innovations SCI_3: Special costs associated with environmental innovation SCI_4: The cost of technological innovation of small enterprises SCI_5: Share of domestic expenditures on R&D, as a percentage of gross regional product SCI_6: ICT expenditures SCI_7: Investments in intellectual property	RCI_1: Investments from abroad in fixed assets, including intellectual property and ICT
Assets	HCA_1: The share of the employed population aged from 25 to 64 years, who has higher education in the total number of employed population of this age group HCA_2: The share of the employed population aged from 25 to 65 years, who passed advanced training and (or) professional training in the total number of employed population of this age group HCA_3: Share of highly skilled workers in the total number of skilled workers HCA_4: Graduation from postgraduate school with thesis defense	SCA_1: Submission of applications by Russian applicants for state registration of intellectual activity results and means of individualization SCA_2: Use of intellectual property SCA_3: Issue of patents and certificates for results of intellectual activity, means of individualization	RCA_1: Number of export agreements
Effects	HCE_1: Employment rate HCE_2:: GRP per capita	SCE_1: Labor productivity index SCE_2: The growth of high-performance workplaces	RCE_1: Technology export receipts under agreements with foreign countries (receipts from engineering services, R&D, know-how, patents for invention, utility models, industrial design, trademarks etc.)

Source: own elaboration based on Stam and Andriessen (2009, pp. 442–451).

Table 2. IC and its components evaluation formulas

Formula for calculation	Explanation
$IC = HC + SC + RC$	HC – human capital, SC – structural capital, RC – relational capital.
$HC = 0.33 \cdot \frac{\sum_{i=1}^{l} HCI_i + \sum_{j=1}^{m} HCA_j + \sum_{k=1}^{n} HCE_k}{l + m + n}$	HCI_i – human capital investments indicators, $i = \overline{1,l}$, l – the number of human capital investments indicators, HCA_j – human capital assets indicators, $j = \overline{1,m}$, m – the number of human capital assets indicators, HCE_k – human capital effects indicators, $k = \overline{1,n}$, n – the number of human capital effects indicators.
$SC = 0.33 \cdot \frac{\sum_{i=1}^{l} SCI_i + \sum_{j=1}^{m} SCA_j + \sum_{k=1}^{n} SCE_k}{l + m + n}$	SCI_i – structural capital investments indicators, $i = \overline{1,l}$, l – the number of structural capital investments indicators, SCA_j – structural capital assets indicators, $j = \overline{1,m}$, m – the number of structural capital assets indicators, SCE_k – structural capital effects indicators, $k = \overline{1,n}$, n – the number of structural capital effects indicators.
$RC = 0.33 \cdot \frac{\sum_{i=1}^{l} RCI_i + \sum_{j=1}^{m} RCA_j + \sum_{k=1}^{n} RCE_k}{l + m + n}$	RCI_i – relational capital investments indicators, $i = \overline{1,l}$, l – the number of structural capital investments indicators, RCA_j – relational capital assets indicators, $j = \overline{1,m}$, m – the number of structural capital assets indicators, RCE_k – relational capital effects indicators, $k = \overline{1,n}$, n – the number of structural capital effects indicators.
Investments $= 0.33 \cdot \frac{\sum_{i=1}^{l} HCI_i + \sum_{j=1}^{m} SCI_j + \sum_{k=1}^{n} RCI_k}{l + m + n}$	HCI_i – human capital investments indicators, $i = \overline{1,l}$, l – the number of human capital investments indicators, SCI_j – structural capital investments indicators, $j = \overline{1,m}$, m – the number of structural capital investments indicators, RCI_k – relational capital investments indicators, $k = \overline{1,n}$, n – the number of relational capital investments indicators.
Assets $= 0.33 \cdot \frac{\sum_{i=1}^{l} HCA_i + \sum_{j=1}^{m} SCA_j + \sum_{k=1}^{n} RCA_k}{l + m + n}$	HCA_i – human capital assets indicators, $i = \overline{1,l}$, l – the number of human capital assets indicators, SCA_j – structural capital assets indicators, $j = \overline{1,m}$, m – the number of structural capital assets indicators, RCA_k – relational capital assets indicators, $k = \overline{1,n}$, n – the number of relational capital assets indicators.
Effects $= 0.33 \cdot \frac{\sum_{i=1}^{l} HCE_i + \sum_{j=1}^{m} SCE_j + \sum_{k=1}^{n} RCE_k}{l + m + n}$	HCE_i – human capital effects indicators, $i = \overline{1,l}$, l – the number of human capital effects indicators, SCE_j – structural capital effects indicators, $j = \overline{1,m}$, m – the number of structural capital effects indicators, RCE_k – relational capital effects indicators, $k = \overline{1,n}$, n – the number of relational capital effects indicators.

Source: own elaboration based on Stam and Andriessen (2009, pp. 442–451).

Table 3. RIC estimation results for federal districts of the Russian Federation, 2017

Indicator / Federal district	Central	Northwest	South	North Caucasus	Volga	Ural	Siberia	Far East
1. Investments								
1.1. Human capital								
HCI_1	1.00	0.30	0.11	0.00	0.35	0.09	0.24	0.05
1.2. Structural capital								
SCI_1	1.00	0.26	0.04	0.00	0.29	0.12	0.12	0.02
SCI_2	1.00	0.21	0.11	0.00	0.48	0.28	0.17	0.09
SCI_3	0.61	0.33	0.07	0.00	0.59	0.30	1.00	0.15
SCI_4	1.00	0.12	0.10	0.03	0.59	0.13	0.41	0.00
SCI_5	1.00	0.81	0.16	0.00	0.66	0.25	0.37	0.09
SCI_6	1.00	0.24	0.15	0.00	0.27	0.16	0.20	0.07
SCI_7	1.00	0.21	0.11	0.00	0.17	0.17	0.13	0.15
1.3. Relational capital								
RCI_1	1.00	0.25	0.58	0.17	0.01	0.15	0.04	0.00
2. Assets								
2.1. Human capital								
HCA_1	1.00	0.48	0.14	0.57	0.10	0.22	0.00	0.39
HCA_2	0.25	0.33	0.48	0.00	0.35	1.00	0.66	0.44
HCA_3	1.00	0.35	0.06	0.37	0.19	0.36	0.00	0.32
HCA_4	1.00	0.32	0.17	0.06	0.46	0.09	0.24	0.00
2.2. Structural capital								
SCA_1	1.00	0.21	0.12	0.00	0.23	0.08	0.16	0.00
SCA_2	1.00	0.17	0.02	0.01	0.65	0.16	0.17	0.00
SCA_3	1.00	0.20	0.11	0.00	0.23	0.07	0.15	0.00
2.3. Relational capital								
RCA_1	0.84	1.00	0.08	0.00	0.42	0.26	0.56	0.01
3. Effects								
3.1. Human capital								
HCE_1	1.00	0.93	0.42	0.00	0.64	0.68	0.35	0.79
HCE_2	0.75	0.66	0.20	0.00	0.29	1.00	0.32	0.74
3.2.Structural capital								
SCE_1	0.45	0.65	1.00	0.00	0.23	0.65	0.45	0.00
SCE_2	0.96	1.00	0.88	0.48	0.74	0.19	0.00	0.44
3.3. Relational capital								
RCE_1	0.47	0.63	0.04	0.00	1.00	0.05	0.14	0.01
Intellectual capital	0.85	0.49	0.23	0.08	0.41	0.29	0.26	0.16

Source: own calculations based on EMISS data.

Table 4. Components of RIC in federal districts of the Russian Federation in 2017

Components of intellectual capital / Federal districts	Central	Northwest	South	North Caucasus	Volga	Ural	Siberia	Far East
The 1st layer of classification								
Human capital	0.29	0.16	0.08	0.05	0.11	0.16	0.09	0.13
Structural capital	0.31	0.12	0.08	0.01	0.14	0.07	0.09	0.03
Relational capital	0.26	0.21	0.08	0.02	0.16	0.05	0.08	0.00
The 2nd layer of classification								
Investments	0.32	0.10	0.05	0.01	0.13	0.06	0.10	0.02
Assets	0.30	0.13	0.05	0.04	0.11	0.09	0.08	0.05
Effects	0.24	0.26	0.17	0.03	0.19	0.17	0.08	0.13

Source: own calculations based on EMISS data.

Table 5. Population of Russian Federation by Federal Districts on January 1, 2017 and on January 1, 2016

№	Federal District	on January 1, 2017	on January 1, 2016
1	Central	39209.6	39104.3
2	Northwest	13899.3	13853.7
3	South	16428.5	14044.6
4	North Caucasus	9775.8	9718.0
5	Volga	29636.5	29673.6
6	Ural	12345.8	12308.1
7	Siberia	19326.2	19324.0
8	Far East	6182.7	6195.0
	Russian Federation	146804.4	146544.7

Source: EMISS (2018).

Figure 1. Percolation lattice at propagation probability p=0.2

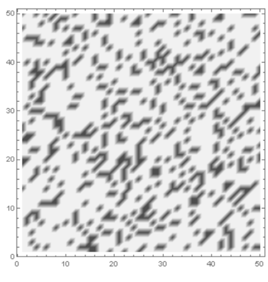


Figure 2. Percolation lattice at propagation probability p=0.59

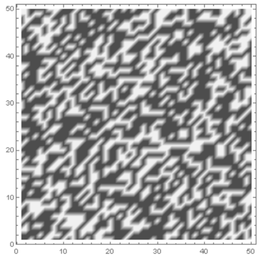
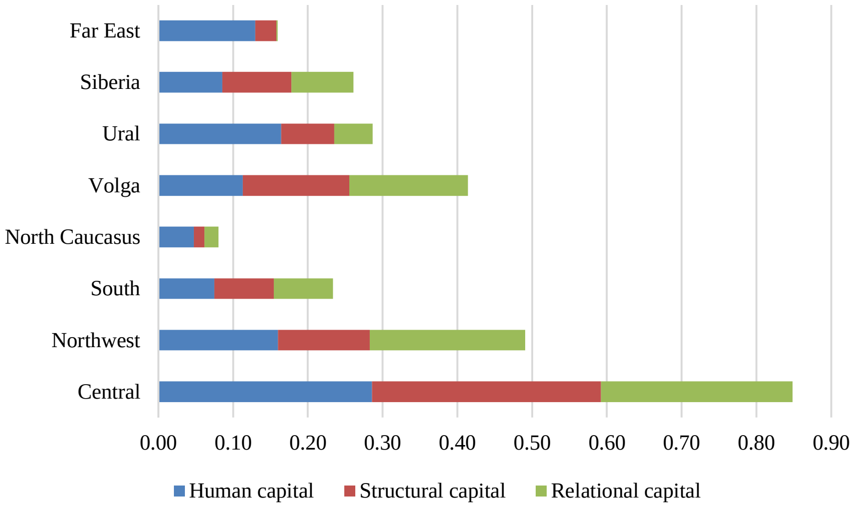
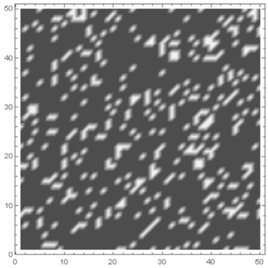


Figure 3. RIC in federal districts of the Russian Federation in 2017

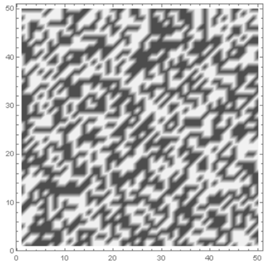


Source: calculated by the author on the basis of EMISS data.

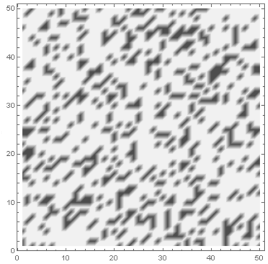
Figure 4. IC percolation in federal districts of the Russian Federation



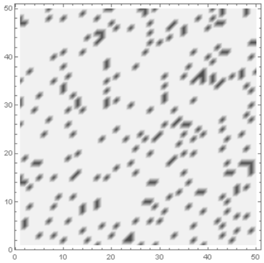
Central Federal District. p=0.85



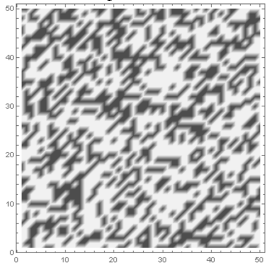
Northwest Federal District. p=0.49



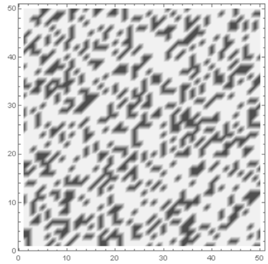
South Federal District. p=0.23



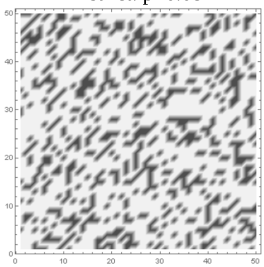
North Caucasus Federal District. p=0.08



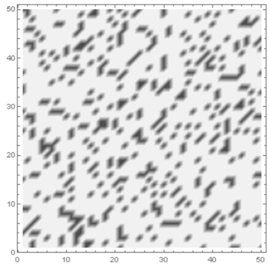
Volga Federal District. p=0.41



Ural Federal District. p=0.29



Siberia Federal District. p=0.26



Far East Federal District. p=0.16