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RESEARCH ARTICLE

Enhancing the knowledge spillover through the formation of the oligocentric national innovation system

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Abstract. The processes of spatial polarization of economic activity and potential of regional innovation systems are an important area of study of the innovation transfer in the global world. The present study continues the scientific discussion on the ratio of concentration and uniform innovation development. The objective of the study is to analyze indicators of spatial concentration of innovation activity and the knowledge spillover between regions in the national innovation system. The main methods are the application of the Herfindal-Hirschman index, as well as cartographic analysis. The analysis of the concentration degree of the following indicators of innovation activity was carried out: patents, developed and used advanced technologies, R&D costs, output of innovative products in these regions of Russia using the Herfindal-Hirschman index. A graphical method was used to identify the main regions of the centers and peripheries, and a map of fragmentation of the country's innovative cores was constructed. The results of the study confirmed the hypothesis of a greater spatial concentration of knowledge in comparison with the release of innovative products. Analysis of potential knowledge spillover between regions showed that the indicators associated with the generation of knowledge, focused on the Russian regions is significantly stronger than the indicators for innovative output: spatial concentration of developed advanced technologies are higher than that used advanced technologies, and the concentration of expenditure on technological innovations ahead of the release of innovative products. This indicates an unbalanced nature of the effects of the innovative spillover, when the use of technologies is more widespread than their development and implementation. Recommendations are also presented on a more efficient organization of the innovation space and on the transition from a monocentric model of organizing a socio-economic space to an oligocentric model to reduce excessive polarization and increase the efficiency of knowledge spillover.

1. Introduction

The spatial aspects of the innovative process study have remained significant for decades. Their complexity is increasing. In recent years, special attention has been paid to the methods of disseminating innovations, primarily the knowledge, based on the beginning of the innovation cycle. Obviously, the characteristics of spillover effects are largely due to the regions specifics in which (or between) they occur. We are talking about the institutional environment, the general level of economic development, the representation of human capital, the development of science and business infrastructure.

The issue of innovation diffusion allows using the centre-peripheral approach. On its basis, the innovation centre and innovation periphery are distinguished. However, this model is more stable with a three-link structure of the centre-semiperiphery (province) - the periphery. It allows to comprehensively considering the processes of innovation generation and distribution, taking place within a country or region in a territorial context. Innovation centres (cores) are regions, parts of regions or cities (depending on the scope of the study), in which the generation of new knowledge is actively happening and from where it spreads to other centres and to the periphery. It is necessary to understand how the center and periphery are formed in the innovation systems and how they can be distinguished.

The framework of revealing the center and periphery is usually based on the amount of knowledge generation and innovative productivity (in value). The first one often apply to difference in patent activity between regions (see for example (Nordensvard et al., 2018). The second one based on the compare of value of innovative production.

At the national level, the authors are considering the country's innovation system. It consists of the next level, represented by regional innovation systems. To characterize national innovation system by some parameters, it's important to consider, that they can be obtained as a result of different contributions and configurations of regional innovation system. The task of regional innovation system is to comprehensively ensure the life cycle of innovation (from start to finish). This means that regional innovation system contains all the necessary components to support the knowledge generation, its transfer and innovation implementation in production. Regional innovation system consists of the subsystems – institutions, providing generation, distribution, support and protection (financial, legal) and the commercialization of knowledge, as well as the

diffusion of innovations. As a result, regional innovation system will be built around research centres, capable of generating knowledge. Not every Russian region has such centres.

The idea of regional innovation system complements the cluster model and focuses on the relationship between cluster members, institutional infrastructure. Those relationships were considered by Asheim & Isaksen (2002); according to them, regional innovation system may contain several clusters. Different actors in cluster and proximity between them makes good conditions to create and accumulate knowledge (Maskell, 2001; Neffke et al., 2011). The general economic potential of the region, the openness of the regional and country economy (including the total cost of high-tech exports), scientific and human potential make possible the interaction of an increasing number of participants, among whom knowledge is spreading, thus strengthening the functioning and development of regional innovation system. It is not only the relative values of the rate that matter, but also the absolute. In other terms, it makes no sense to consider various dynamics indices and comparison coefficients if the total value of investments, innovative products, etc. close to zero .

An important property of regional innovation system is self-sufficiency, which is understood as the ability of a system to carry out the entire chain of the innovation process: from generating knowledge to obtaining finished products, i.e. the availability of subsystems science-innovation-industry. Evidently, self-sufficiency does not mean closure. Flexible regional innovation system is distinguished by a combination of its own regional and exogenous knowledge use. This combination of external and internal knowledge makes it possible to generate radical innovations, that can ensure high competitiveness (Country features…, 2019).

Another model involves the use of external knowledge, technologies, coming from world innovation centres. Asheim, one of the developers of the regional innovation system theory, distinguishes three types of regional innovation system: by the degree of openness, by the combination of local and external knowledge (Asheim et al., 2011). Thus, two types of knowledge are disseminated in regional innovation system: created in this system and obtained from the outside.

Nevertheless, the prevalence of external knowledge puts the economy, based on them, in a position of catching up. External knowledge, as a rule, is already commercialized in world innovation centres. The production, based on them, can strengthen the position of the region in the country division of labor, but will not help to enter the already developed world markets.

The aim of this work is to substantiate the identification of the knowledge spillover between regions, based on rates of the innovation spatial concentration. For this, it is necessary to identify the regions-centres, regions-provinces and regions -peripheries. The main method of the research is the use of the Herfindahl-Hirschman index , as well as cartographic analysis. This will make it possible to spatially identify those regions, in which the development of innovative activity will contribute more to the development of the entire national innovative space, as well as enhance the knowledge spillover.

A spatial analysis of the region innovation activity is necessary to make recommendations for a more efficient organization of the innovation space in Russia; in particular, the significance of the transition to the functioning oligocentric model of the national innovation system is substantiated.

2. The Methods

In international practice, the Herfindahl-Hirschman Index is used to assess the level of market monopolization. However, in practice it turns out to be suitable for assessing the concentration level of a certain rate in a territorial aspect. The level of concentration and its change in time are very important, in particular strengthening or weakening (deconcentration). To assess the innovative rates in the Russian regions, the authors used the Herfindahl-Hirschman index (HHI), its value was determined by the following formula:

$$HHI = \sum Yi^2, \quad (1)$$

where Yi – the share of the i-th region rate to the total value.

The obtained results should be interpreted as follows: the closer Herfindahl-Hirschman Index is to 0, the more evenly the studied attribute is distributed across regions, and the closer to 1, the greater is its concentration in one of the regions (Preobrazhenskiy & Firsova, 2019). The following rates were used for calculations: patents for models and inventions developed and used advanced technologies, costs for R&D, costs for technological innovations, production of innovative products according for 2017.

There are a lot of methods, that allow to measure the concentration of some economic processes (see for example (Kopczewska, 2018). Apart from HHI, most widely used is Gini index, Theil's index and other. Actually the results they all give, are similar. If, for example, one sector is more concentrated than another, according to calculations using one of these indices, it will also show a greater concentration in calculations with another index.

The HHI does not take into account the square of the region and amount of it's population, nevertheless, this is a kind of factor that was already taken into account, since the positive effect of agglomeration has been sufficiently studied since Marshall.

For more in-depth research we can use indices of concentration by region, most common used is Location Quotient. But in the case of Russia, where is more than 80 regions, the indicators, that describes the whole country, are more representative.

A comparison of the degree of concentration of different innovative related indicators suggests that the decrease in concentration occurred as a result of a certain process. So, if the degree of concentration of used technologies is higher than the degree of concentration of created technologies, it means that there is a process of spreading innovation. HHI demonstrate the spatial unevenness of some economic and innovative activity, that is a significant condition to identify the possibility of spillover effect. The weakness of this method is that you need to clarify, where specifically this unevenness reveal itself. On this basis we add the cartographical analysis along with graphical analysis of the costs of R&D and their magnitude in the regional economy. Cartographic material allows to visually highlight the core of the national innovation space. The information base of the study is the data of the Federal service of the state statistics of the Russian Federation and Unified interdepartmental information-statistical system of UNISIS.

3. Result and Discussion

As a result of the use of Herfindahl-Hirschman Index, the following values were obtained (Table 1). They are arranged from top to bottom in ascending order of Herfindahl-Hirschman Index, i.e. gain concentration.

Obviously, the most significant concentration by region in the field of R&D costs. By analyzing the specific values, we can see how clearly expressed is the group of regions, that significantly outstrips all the others, primarily Moscow, Moscow Region, St. Petersburg, Tatarstan, Nizhny Novgorod Region. Significant concentration is observed and the concentration of patents for inventions and models. These rates, related to the knowledge generation, are concentrated more strongly in Russian regions, than rates related to the production of finished products. This can be interpreted as the potential of the knowledge spillover between individual science-oriented regions and others, in which this knowledge is adopted and used.

We note two interesting inequalities. Thus, Herfindahl-Hirschman Index in territorial concentration of developed advanced technologies is higher, than the used advanced technologies, and the concentration of costs for technological innovations is ahead of the release of innovative products. Both of it testifies to the presence of the innovative spillover effect, when the application of technologies is wider than their development and implementation.

Territorial distribution of innovations, intersectoral differences and power of different factors influence on the processes of innovation regional development attract a lot of attention and are studied in foreign and domestic literature to search for potential mechanisms by which they can stimulate regional innovation and economic growth (Autant-Bernard, 2001; Monteiro et al., 2011; McCann & Ortega-Argilés, 2013).

In the research of national innovation systems, the authors pay great attention to factors affecting the effectiveness of their functioning (Brenner & Broekel, 2011; Firsova & Makarova, 2017; Makarova & Firsova, 2017; Chelnokova & Gritsak, 2013; Wang & Zhang, 2018). In conditions of considerable geographical distances, the so-called proximity is especially important for Russia, which provides conditions for the interaction of scientific and economic actors, the flow of knowledge (Wang & Zhang, 2018; Firsova et al., 2019). In addition to geographical distances, factors such as cognitive, institutional, organizational, and social distances are important (Boschma, 2005; Aldieri, 2011; Davids & Frenken, 2018; Kijek & Kijek, 2019).

The polarization of space, on the one hand, creates conditions for such proximity, on the other hand, prevents interaction between the centers. The process of disseminating knowledge is difficult (Rogers, 2003; Costantini & Liberati, 2014; Newman et al., 2015).There is a discussion in regional science about the ratio between concentration and uniform spatial distribution of the main components of economic and innovative development. On the one hand, concentration allows the use of economies of scale and synergies: a combination of a variety of scientific and production processes, together with an extensive demand for their final results (i.e., development and innovative products). The beneficial effects of concentration have been described by a number of researchers (Venables, 1994; Krugman, 1996; Dudzevičiūtė & Tvaronavičienė, 2011).

On the other hand, excessive concentration leads to significant in-country differences, creating risks of the country degradation. Economic problems lead to a drop in living standards and social discontent. The problem of this dichotomy is known as “Equity vs. Efficiency”. Competition for resources is increasing in the cores themselves (Torre & Darly, 2013). Many countries have set the goal of deconcentrating their centres. A typical example: the excessive role of Seoul and Pusan in South Korea economy in the 70-90s. As a rule, part of the centres still continue to concentrate on their territory a disproportionate share of the country's scientific and production potential.

Obviously, finding a balance between the two extremes is relevant at various stages of a country's development, and the optimum concentration criteria may be unique for each country. In the case of Russia, the initially low population density of the country attracts the attention, which leads to low density and territorial gaps in economic processes. It is no coincidence that within the Soviet economic regionalization framework, the nodal area theory was appeared and developed, based on a linking centre (node) that organizes the adjacent territory. It is also no coincidence, that in the post-Soviet period the idea of “Internal periphery” – regions was appeared; it did not have a growth resource either on the basis of raw materials export or on the inclusion in the process basis of in-country division of labor.

Polarization processes continue to take place in the socio-economic Russian space: some regions increase their absolute and relative indicators at the expense of others. It could be said that the former are more efficient in managing their resources, but in reality, mechanisms have been created in

Index	HHI
Used advanced technologies	0,02959
Release of innovative products	0,04777
Developed advanced technologies	0,05328
Technological innovation costs	0,05528
Model patents	0,07919
Patents for inventions	0,09851
R&D costs	0,16192

Table 1. HHI value for various innovative rates by Russian regions, 2017

Source : Calculated by authors, using data from Federal State Statistics Service (Rosstat), 2019. Available from: http://www.gks.ru Unified interdepartmental information-statistical system of UNISIS, 2019. Available from: https://www.fedstat.ru

the country for unequal exchange between regions. In particular, the headquarters of a significant part of all companies - major exporters of mineral resources are located in Moscow and St. Petersburg. Moreover, the headquarters receive profit from their activities and taxes. Another problem is the imbalance in federal and regional taxes towards the first of them.

The relation between the formed core and the rest of the space are conveniently described using the centre-periphery model (Preobrazhenskiy, 2016). In this research the authors distinguish a centre-peripheral system, based on the generation of knowledge and on the basis of the innovative product production. We believe that the former will be characterized by a relatively smaller number of centres and a larger periphery. The authors assume that such a mismatch is a prerequisite for the knowledge spillover.

The analysis of the concentration of economic indicators by regions of Russia using HHI for 1990-2013 revealed that investments in fixed assets are more sensitive to changes in the economic environment. They tend to concentrate in several regions (Rastvortseva & Ternovsky, 2016). Morettini et al. conducted a study of the concentration of intellectual activity in Italy at the local level (Morettini et al., 2013) using Gini index. Unfortunately, Russian statistics do not publish results of innovation activity at levels below the regional level, which makes it difficult to identify specific spatial contours of innovation activity.

It is also important to consider absolute values of R&D costs. As can be seen from the graph (Figure 1), only three regions exceeded $ 1.5 billion in total R&D costs: Moscow and Moscow Region, St. Petersburg. It may seem that 2–3% of R&D costs of the total gross regional product (GRP) in these regions is quite high, however, within the country, as a whole, it is low. In the absence of other large centres, Moscow and the region, as well as St. Petersburg, must generate innovations for the whole country. As a result, the bicentric configuration of the knowledge generation system in Russia is noded.

The transformation of the Russian socio-economic space, in the direction of reducing the process concentration of generating new knowledge, will allow the latter to more efficiently spread among the actors of innovation, and also generally increase the diversity of the national innovation system, give it greater flexibility, which will allow the transition to the process of expanded innovation reproduction.

In light of the foregoing, the most optimal objective of regional policy is the transition from a monocentric model of the socio-economic space organization to the oligocentric model. This means the formation of full-fledged regions as economic and innovation centres. Their number is not too large (less than a dozen); however, such organization will strengthen the entire socio-economic space of the country and stop the continuation of excessive polarization (or rather, increase the number of polarization centres). Connections between the cores will be supported by development axes, the mechanism of its functioning is described by Pottier (1963).

In that case there will remain a gap in the indicators of knowledge generation concentration and output. However, it is expected to minimize the gaps between the use of advanced technologies, the release of innovative products and the total volume of output.

Analysis of the map (Figure 2) allows to identify, firstly, the small number, and secondly, the fragmentation of the country's innovative cores. Note that some part of them coincide with the location of the R&D centre regions, while the other (the Ural-Volga region) does not. Right here there are potential cores for the transition to the oligocentric system, which was discussed above.

4. Conclusion

The According to the hypothesis mentioned at the beginning of the article, the degree of knowledge concentration is greater, than the innovative products output. Centre-peripheral systems, based on the innovation cycle, have a much greater degree of polarization in relation to knowledge, compared to production. This situation creates

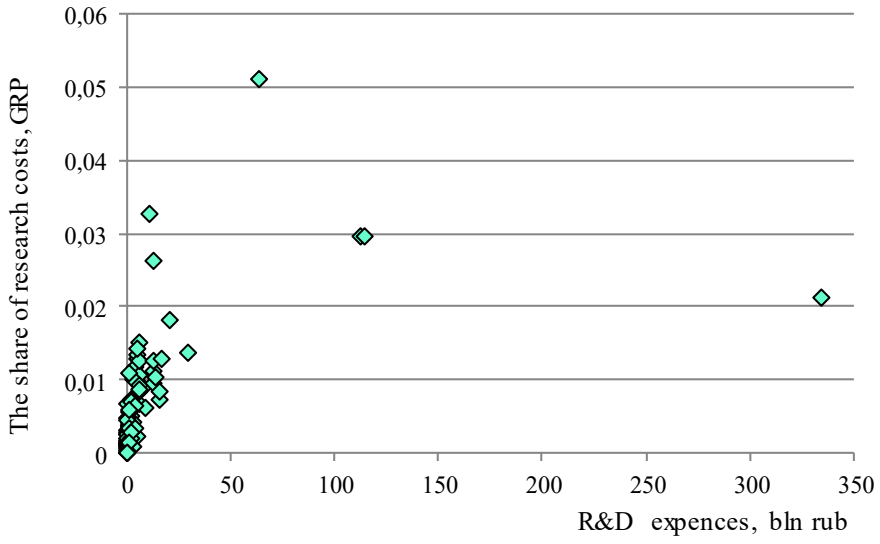

Figure 1. Absolute and relative rates of the scientific activity cost in Russian regions
Source: Compiled by the author, using data from Federal State Statistics Service (Rosstat), 2019. Available from: http://www.gks.ru Unified interdepartmental information-statistical system of UNISIS, 2019. Available from: https://www.fedstat.ru.

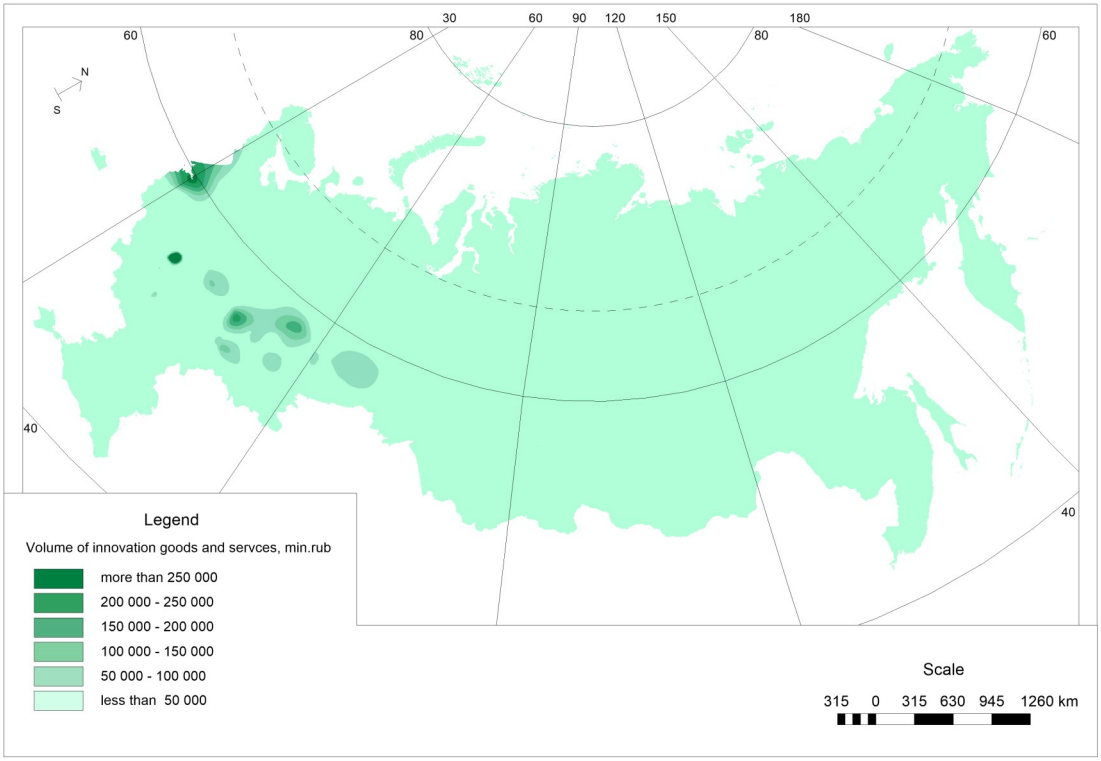

Figure 2. Volume of innovation goods and services, mln rub, 2017
Source: Compiled by the author, using data from Federal State Statistics Service (Rosstat), 2019. Available from: http://www.gks.ru Unified interdepartmental information-statistical system of UNISIS, 2019. Available from: https://www.fedstat.ru

several consequences. Firstly, an excessive knowledge concentration in some places (cities) leads to development risks, since at the mesoscale many regions are not able to generate new knowledge by themselves, and the mechanisms of its dissemination are largely determined by the distance to the scientific centre. It also means that knowledge spillover between regions, that generate knowledge and regions that produce products. In territorial terms, the complementarity of science and production is necessary, that's why regional innovative systems of the mesoscale are an important basis.

The applied method using HHI is not the only one, that could be proposed for measuring the concentration, but combining it with graphical analysis, it shows the convincing result. The model can be compared to the layers of the onion, where the generation of knowledge is centered and it needs to penetrate all the way to the outer shell. Still the more in-depth research based on calculation of regional concentration's indices is needed. Also the dynamic of changing of these indices lies in the line of furthermore research.

We believe that the proposed mechanism can become a tool for assessing the effectiveness of regional authorities in the field of innovation. The dynamics of the ratio of indices by years is able to show the direction of a decrease or increase in the polarization of the innovation space. In the case of a country as large as Russia, it is necessary to develop research centres and knowledge transfer infrastructure in several large zones. Currently, such centres exist, including in Siberia (primarily Novosibirsk, Tomsk), but their funding is insufficient, and the territory of the potential innovation spread is limited. In fact, we can talk about the archipelago of scientific centres, that lack activity to communicate with each other. The latter poses risks of pupation, shorting and degradation in the long run. The transition from a bicentric to an oligocentric configuration of the national innovation system will enhance the knowledge spillover. The need to create full-fledged regional innovation systems is critically important for the technology development and the release of related products. This task is especially important for large countries where the concentration of scientific and innovative resources in one place leads to risks of lagging behind for the rest of the territory. The diversity aspect is important. Different regions can implement their own unique developments and commercialize them. This will lead to a revival in domestic trade and allow the country to become more flexible in the global market.

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