Innovation geography of Russia

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Abstract. Spatial characteristics of innovation processes in Russia was investigated. Method of 'innovation trace' is considered as a promising toolkit for research of territorial social and economic systems (*TSES*)[1] development. Potential applications of the scientific method are illustrated on an example of city system dynamics and patent field of Russia with the subsequent forecasting of innovation clusters formation by 'Foresight' methodology. This article is an original work of historical and geographical study of innovation processes. A unique authors' database of the previously preexisting and existing cities in Russia was used. It is one of the rare works in the public domain, which are devoted to the study of innovation capacity of the USSR regions. Practical importance of the work is the use of 'Foresight' methodology for identification and formation of innovation clusters in certain critical technologies.

1. Introduction

'Innovation' is one of the most important and topical subjects both abroad [1], and in modern Russia. There is a quite significant body of work in economics and sociology of innovation, but studies in the field of innovation geography are extremely rare in Russia, especially papers of history-geographical innovation patterns. The object of this research is an innovation space of Russia, and its patterns in past, present and future. The main purpose of the study is to identify key features of innovation development in Russia. Geographical issues are connected with the 'wave-particle' nature of innovations, which is expressed in generation of innovations in certain centers ('particle') and their diffusion in space ('waves'). The paper deals with historical and geographical analysis of cities origin as centers of generation and absorption of innovations. Innovation waves, in the most concentrated form, in frameworks of civilization processes, are shown in settlement system formation. Obviously, largest and polyfunctional cities are basic sources of technological inventions; new quickly growing cities are strongest acceptors, actively absorbing innovations from all the spheres of territorial social and economic systems (TSES). According to this approach, a process of cities network formation can serve as an indicator of innovation diffusion within the Russian space and as an object of innovation geography. Cluster analysis and a method of 'field potential' were used to analyze territorial structure of innovation sphere on an example of patent activity in Russian regions. The analysis of interrelation between innovation distribution density and city distribution density has shown a presence of direct correlation between two TSES characteristics. On the final stage of research, 'Foresight' methodology helped to reveal and predict existing and forming regional innovation clusters.

[1] States, regions, cities, and etc. can be attributed to TSES

2. Research methods

The 'innovation trace' technique, based on a time-space analysis of cities occurrence process, has been applied for studying of innovation waves. The following system of indicators was used:

- Scale of innovation process (quantity of arisen cities for a time interval – cities / 50 years);
- Intensity of innovation process (density of cities occurrence – cities / 50 years / 100 thousand km²);
- Cumulative density of cities (cities / 100 thousand km²);
- Area captured by innovation process (area of emerged cities on a territory in an interval of time);
- Rate of renovation of city system (relation between a number of arisen cities and a number of cities inherited from previous stages of development).

Two main *indexes* can reflect spatial laws in distribution of city generation: index of density and intensity of innovation waves [2].

The index of time-space density of an innovation wave (Eq.1) is given by the following equation:

$$Id = \frac{Kg(t)}{S_i} \quad (1),$$

where Id is an index of density of an innovation wave (cities on 100 thousand sq. km. for a time unit); $Kg(t)$ is a number of cities which have arisen for a time unit (50 years); S_i is an area of *i- th* cell of territory.

The index of intensity of an innovation wave (Eq. 2):

$$In = \frac{Kg(n)}{Kg(s)} \quad (2),$$

where In is an index of intensity of an innovation wave; $Kg(n)$ is an number of cities which have arisen on a territory for a time interval; $Kg(s)$ is a number of cities which have arisen in a previous time interval.

Cluster analysis and 'field potential' method was used to estimate accumulated innovation potential of different TSES of the former Soviet Union and contemporary Russia. The following equation (Eq. 3) of field potential was applied:

$$V_j = P_j + \sum P_i / D_{ji} \quad (3),$$

where P_j is a value of an indicator (number of registered patents) in point for which the potential is defined; P_i is a value of an indicator in other points; D_{ji} is a distance from a point *j* to *i*, km.

The complex of techniques for a long-term technological development forecasting (Foresight) has been used. It includes all set of methods of exploratory technological forecasting [3], which begins with an estimation of knowledge basis, available at present, and it is focused on future of standard forecasting, originally estimating future purposes, requirements, desires, missions, etc. and going in the opposite direction - to the present.

The special index has been developed for allocation of innovation clusters. The equation of linear scaling was used to compare different scientific centers (Eq. 4):

$$I_i = \left(X_i - X_{\min}\right) / \left(X_{\max} - X_{\min}\right) \quad (4),$$

where I_i is the index, X_i is an investigated figure, X_{min} is the smallest element in a group of compared figures, $X_{\max}$ is the greatest figure.

3. Discussion of results

3.1. The emergence of cities as an indicator of innovation process

The research of the history of Russian cities occurrence allows allocating five big stages (Fig. 1). These stages, applying on a map, also can be clearly reflected in space [2].

1. Until the middle of the XI century (200 years), the urban innovation process has arisen as a result of primary settlements' network formation on the territory of about 1 million km² with 19 cities (an average rate for a century was 7). It was a consolidation period of the Slaves state in Central and Northwest regions of historical Russia.

2. Prior to the beginning of the XVI century (450 years), the innovation wave of city foundation, on the one hand, compacted, creating a dense network of settlements on territories of the former development, on the other hand, a network of newly developed areas in the European north and west of the Urals was creating. Throughout this period, the spatial extent of primary-secondary urban innovations reached 1.3-1.7 million km². The average density is monotonously increased from 0.23 to 0.31. Within this period, it is already possible to distinguish three well-defined 150-year cycles.

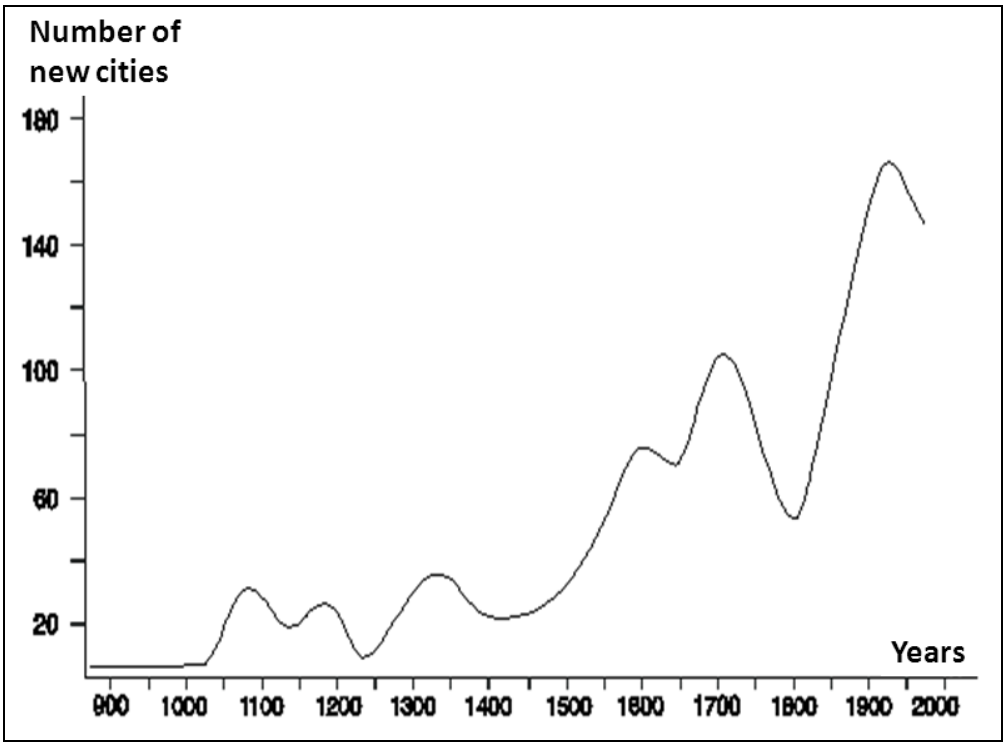

Figure 1. Dynamics of city occurrence on the territory of Russia in years.

3. The third wave of urbanization covers three centuries (from the first half of the XVI century till the first half of XIX century). It is the period of unprecedented expansion of borders of the Russian state from 4.5 million km² by the end of the XVI century to more than 9 million km² by the end of the XVIII century. The density of urban settlement is significantly decreased in spite of growth in the number of appearing cities. In the given period two 150-year-old cycles are accurately allocated.

4. The fourth period, from the first half of the XIX century, coinciding with the beginning and continuance of industrial civilization, has 150-200 years duration. The period is characterized by an explosive growth of emerging cities in the first two postwar (World War II) decades. Its time boundaries are well fit for the 1st, 2nd and 3rd cycles of *Kondratiev* [4], calculated for Russia and the USSR. The downward phase of the cycle coincides with the fourth Kondratiev wave, and in fact demonstrates the completion of industrialization and related industrial urbanization [2].

5. The fifth (future) period, presumably, is synchronized with the post-industrial civilization, 150-years urban cycle of J. Forrester [5], and corresponds to virtual representations of suburbanization and information society [6].

The urban structure of Russia, formed by 2000 as a result of innovation waves diffusion such as Kondratiev cycles, retains all the major spatial features, fixed in its urban spatial structure by 1550. The curve (Fig. 1) of new cities emergence resembles a curve of noncumulative innovation diffusion in TSES (before the point of saturation), firstly described in geography by T. Hagerstrand [7].

The calculations have shown that up to the middle of the XVI century all-Russian city innovations were located in the Volga-Oka interfluve, and partially on the North-West of East-European Plain after XVII century. In the XVIII century leadership passed to the Ural-Kama region. The last 150 years Eastern Russia, Siberia and Far East, have taken the lead. The XX century is characterized by a maximum diversification of urban innovation by regions of Russia, which corresponds with the general policy of equalization of territorial differences [2].

3.2. The dynamics of innovation field potential

Formed urban structure determines the ability of territorial systems to generate and extend technological, social and economic innovations [8]. The proof of this thesis is the study of patenting activity in Russian cities. The typology of the USSR regions in 1992, based on cluster analysis (the number of patents registered and used), showed that innovation "core" of the Russian civilization is mainly concentrated in Moscow region [8], but there were a number of other centers: Saint Petersburg, Volga region, Tomsk, Kiev, Kharkiv, Minsk regions, and others. After the collapse of the Soviet Union a single innovation space was divided into a number of isolated and poorly connected centers [9], some cores remained outside Russia and finally lost their functions (Yerevan, Tashkent, and others).

The thesis is proved by the help of the private space model "patent field potential", which describes an innovation trace of urban waves and related activities. The field grows on the recovery phase, the area extends and the density increases. On the crisis phase the field is weakened and eroded, becoming more contras. The scale of the economy decreases, the proportion of depressed elements of the system increases, and density reduces (Fig. 2), how it was happened from 1989 to 1999. The analysis of interrelation between city network density and innovation potential has shown a presence of direct correlation [2].

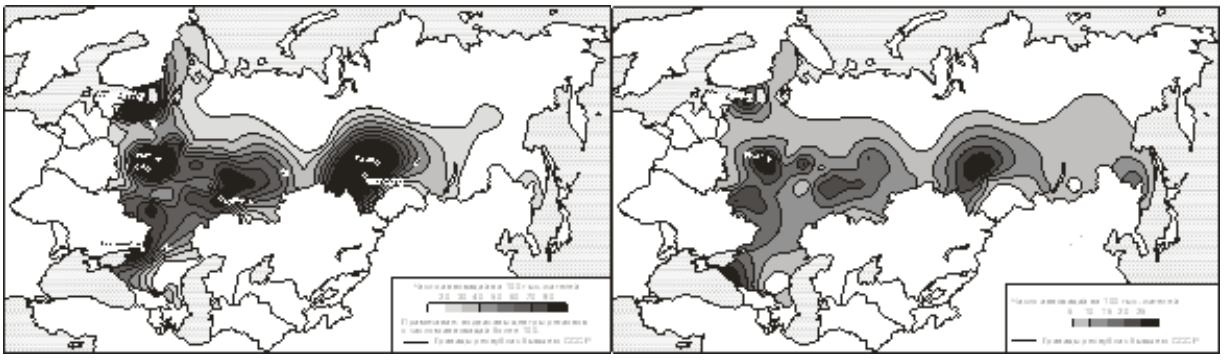

Figure 2. Dynamics of patent field potential on the territory of Russia between 1989 and 1999. The figure shows the density of the innovation; the more intense the color, the higher the density of the invention (patents) is.

The conducted researches suggest evidence of interrelation between cyclic processes in nature and society and a change of scale and basic properties of space. There is an oscillatory contour, in which natural-historical and social-economic spaces are changing their scale, configuration, and density structure under the influence of nonlinear processes in nature and society [8]. The understanding of these mechanisms is an important factor for a long-term forecasting of innovation processes.

3.3. ‘Foresight’ methodology in forecasting of technological development and identification of key innovation clusters

The ‘Foresight’ methodology used to predict a long-term development of innovation processes. The technique made it possible to distinguish three alliances (or ‘industrial’ clusters [10]) of a critical technology "Rational nature management". The most powerful alliance includes the following areas: monitoring, modeling and forecasting of environment changes; technologies for estimation and rational use of natural resources; technologies of landscapes and biodiversity conservation; waste management, water and air purification technologies. This cluster can be conventionally named ‘environmental’.

The final product of the critical technology are high-tech services such as space sensing and monitoring, supercomputer meteorological analysis and forecasting, geographic information systems development, and etc. Technologies themselves are organized in the framework of innovation cycle. Part of the field can be attributed to the "creative industries" [11].

A number of key innovation centers has been identified during the research; numerous statistical data and expert interviews were used for this purpose. Competences of universities in the identified areas, and their cooperation (number of interactions) with scientific organizations and enterprises, presence and number of centers for technology transfer, as well as implementation of modern innovation projects during the last 5 years have been the key indicators.

The primary analysis showed that environmental cluster includes more than 30 experts, 10 university centers of forecasting, and 15 high schools, participating in the network. They interact with 20 other universities, 40 research organizations and more than 60 enterprises.

The integral index, consisting of the previous factors, has been calculated for each innovation center, using the method of linear scaling. Moscow innovation center intends to be excluded from the analysis because of its high values, which do not allow the correct use of the method. The distribution and interaction of innovation centers is shown on Fig. 3.

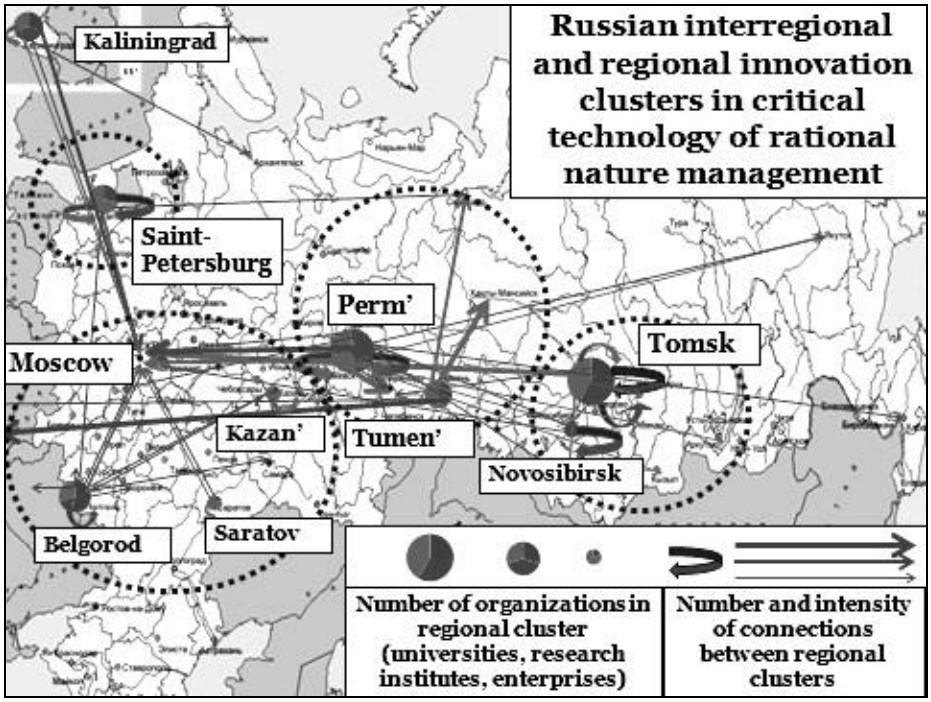

Figure 3. Scheme of Russian innovation centers and interregional clusters of the critical technology.

This technique reveals the number of regional and interregional clusters. Regional clusters [10], which include in order of importance Tomsk, Saint-Petersburg, Tumen’, Perm’, Kaliningrad, Kazan’, Novosibirsk, Belgorod, and Saratov regional centers, are detected by a high value of the integral index,

high concentration and interaction of the organizations. Interregional clusters, including Central, Siberian, Ural and North-West zones, are allocated by major vectors and spheres of interaction. Identified centers are vital for the critical technology.

4. Summary

The conducted analysis has shown that the methodology of innovation trace, used with a number of mathematical, statistical, geographical and 'Foresight' methods, demonstrates the possibility of the method to be adopted for research of previous and future processes in TSES.

The resulting illustrations (Fig.1, 2, 3) and the previous calculations indicate a high correlation between the territorial structure of urban innovations over the last 5 centuries, the innovation potential of existing cities in Russia and the emerging territorial structure of innovation centers for prediction of scientific and technological development in the 'environmental' critical technology.

The research work suggests several important conclusions about innovation geography of Russia:

1. pronounced center-periphery model of formation and modern organization of Russian innovation space;
2. Moscow region is the Russian largest innovation center for the past five centuries;
3. high concentration of Russian innovation potential in a limited number of centers;
4. the largest cities are the centers of generation and innovations diffusion to the periphery;
5. the emerging innovation clusters in the critical technology of 'rational nature management' repeated and preserve the territorial structure of existing innovation space.

Future research directions will involve assessment of the current innovation capacity of Russian regions, as well as development of creative industries in big cities, especially after the Olympic Games in Sochi and the FIFA World Cup in 2018. The identified clusters require subsequent verification.

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