SCIENTOMETRIC MAPPING: ON CREATING A DATABASE FOR INNOVATION DYNAMICS OF URBAN SETTLEMENTS

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Abstract

The geography of knowledge and innovation is highly uneven throughout the globe. Capital cities and metropole areas are generally the leaders in innovation activity acting as core of the national innovation system. Major cities accumulate financial capital, highly skilled labour, creative industries, high-tech businesses, start-ups. Advanced public facilities and strong higher education institutions also attract research-intensive industries and generate university spinoffs. While featuring the diffusion of positive externalities on to the adjacent settlements, the core urban settlements intensify the divergence of the national space in the knowledge, innovation and technology domains. Our study tests the hypothesis on the backwardness of the outlaying territories. It stresses on the role of smaller cities and towns in the national knowledge context. The research methodology on creating a database on the knowledge distribution across Russia in grounded on scientometric mapping tools available in SciVal analytical toolkit. A total number of 998 settlements are analysed with 222 selected for the in-depth evaluation. Results suggest that national innovation system is a complex organism of mutually dependent elements. Often underestimated, smaller cities are found to be vital both within the national innovation process and as self-sufficient centres of the global network of research and development.

Key words: knowledge geography, innovation geography, scientometrics, regional innovation system, knowledge management

JEL Code: O32, O33, O34

Introduction

National innovation system (NIS) is a concept first introduced by Freeman (1987) after studying the highly centralized entrepreneurial network structure of Japan (in comparison with the USA). Later scholars have introduced the notion of Regional Innovation System – RIS (see: Cooke et al., 1997). The observations are made on analysing the coherent territorial innovation systems at regional level. Individual regions are found to have distinct

development trajectories, self-sufficient (independent from the centre) and complete systems for innovation composed of knowledge-generating institutions, businesses that are eager to adopt and commercialize the new knowledge, the public institutions that undertake support functions, etc. Moreover, regions are active in internationalization. Companies and higher education institutions (HEIs) are integrated in the global value chains and innovation networks (Pietrobelli & Rabellotti, 2009; Yeung, 2015), they undertake implement innovation strategies that might even contradict national innovation security interests (Mikhaylova, 2018). Therefore, the geography of knowledge and innovation is not just asymmetrical in the core-periphery pattern, but it is also diverse in terms of its compositions, capabilities, development goals, etc.

For building a complete picture of the variety of RIS that constitute highly heterogeneous NIS, the spatial distributions assessment is required. Regional profile is defined by its territorial capital – the availability of intellectual, industrial, financial and other resources available on spot (e.g. see: Capello et al., 2011). Moreover, the geo-economic position (incl. its physical location in relation to other territories) plays a significant role in determining the structure of the regional economy, the composition of actors and their specialization, the vector of ties (incl. the key trade partners), etc. As noted by Porter (2000), the location remains to be the decisive factor of competitiveness. The reasoning behind this statement changed over time. First, the proximity to raw resources sculpted the national settlement structure. Mono-cities plumped across the globe. Today, in the times of the service-driven economy, the proximity to knowledge resources start to shape the localization of entrepreneurs. Being highly mobile and yet rooted and path-dependent all at once, knowledge geography is fragmented to old – long established industrial centres and new – science and technology driven poles.

Despite the sophisticated level of contemporary statistics, knowledge remains elusive and implicit. One of the available means to capture and evaluate knowledge is scientometrics. Numerous studies are held for analysing the knowledge domain of the territorial capital of individual regions and states (Bornmann & Waltman, 2011; Uddin & Singh, 2014; Zhou et al., 2009). Singh et al. (2015) have elaborated in the concept of scientometric mapping. Despite of the title, however, it implies a construction of thematic clusters of data using a set of bibliometric criteria – subject area, affiliation, collaboration patterns, etc. Spatial scientometric mapping is rarely implemented due to methodological complexity and the fact that it requires utilization of research methods from different disciplines. An example could be the study held by Csomós (2017) on mapping the scholarly output of 2200 cities

worldwide. We apply spatial scientometric mapping using human geography perspective in order to capture and identify the patterns behind the distribution of knowledge domain of RIS within a single NIS of the Russian Federation. The hypothesis put forward suggests that knowledge is both mobile and rooted, being dependent on new and long established competitive advantages of regions.

1 Methodology

Scientometrics is a relatively new source of quantitative data available in millions of records. It covers all countries of the globe using a single data template for all, which is unachievable with regard to general statistics. Moreover, scientometrics is focused on capturing tacit knowledge that is elusive for conventional statistics. Spatial scientometrics is a new methodological perspective of bibliometric data analytics. It is concerned with projecting knowledge excellence on to regional divide. The data provides insight on the localization, cooperation, specialization and other patterns in its dynamics.

The research scope covers 998 settlements of the Russian Federation located in 83 subjects (21 republic, 9 Krai, 4 Okrug, 2 cities of Federal importance – Moscow and Saint Petersburg, and 27 Oblast, incl. 1 autonomous Oblast). The data excludes the Republic of Crimea and the federal city of Sevastopol, as Scopus database is inconsistent in country affiliation of records. The bibliometric data is taken for a five-year period from 2013 to 2017 using peer-reviewed publications (scientific journals, books, and conference proceedings) of the largest abstract and citation database – Scopus. According to the Russian electronic library (www.elibrary.ru), these are under 10% of all papers published by Russian organisations during period. However, these are only high-end research of globally competitive excellence clusters.

The query string made in Scopus Advanced search form is based on both the affiliation city (Field code – AFFILCITY) and, in case of availability, the code of validated organizations located in this city (Field code – AF-ID), and the affiliation organization, in order to capture publications with no affiliation address (e.g. Immanuel Kant Baltic Federal University OR Immanuel Kant State University of Russia OR I. Kant Baltic Federal University OR Kaliningrad State University OR Kant Baltic Federal University OR Baltic Federal University OR I. Kant Russian State University OR Kant Russian State University OR Immanuel Kant Baltic Federal University OR IKBFU OR Baltic Federal University of I. Kant). The total variation of settlements is found in the report On the results of the all-Russian

population census of 2010 available at the Russian Federation Federal State Statistics Service – Rosstat (see: URL: http://www.gks.ru/free_doc/new_site/perepis2010/croc/perepis_itogi1612.htm [*In Russian*]). Rosstat database is also used for population by settlements (see: URL: http://www.gks.ru/wps/wcm/connect/rosstat_main/rosstat/ru/statistics/publications/catalog/afc8ea004d56a39ab251f2bafc3a6fce [*In Russian*]).

Each search request is done individually per settlement. An example for the city of Kaliningrad: "AFFILCOUNTRY (Russia*) AND AFFILCITY ("Kaliningrad") OR AFFILCITY ("Bagrationovsk") OR AFFILCITY ("Guryevsk") OR AFFILCITY ("Gusev") OR AFFILCITY ("Zelenogradsk") or (AF-ID ("Immanuel Kant Baltic Federal University" 60031254) OR AF-ID ("Kaliningrad State Technical University" 60018744)) AND (LIMIT-TO (PUBYEAR , 2017) OR LIMIT-TO (PUBYEAR , 2016) OR LIMIT-TO (PUBYEAR , 2015) OR LIMIT-TO (PUBYEAR , 2014) OR LIMIT-TO (PUBYEAR , 2013))".

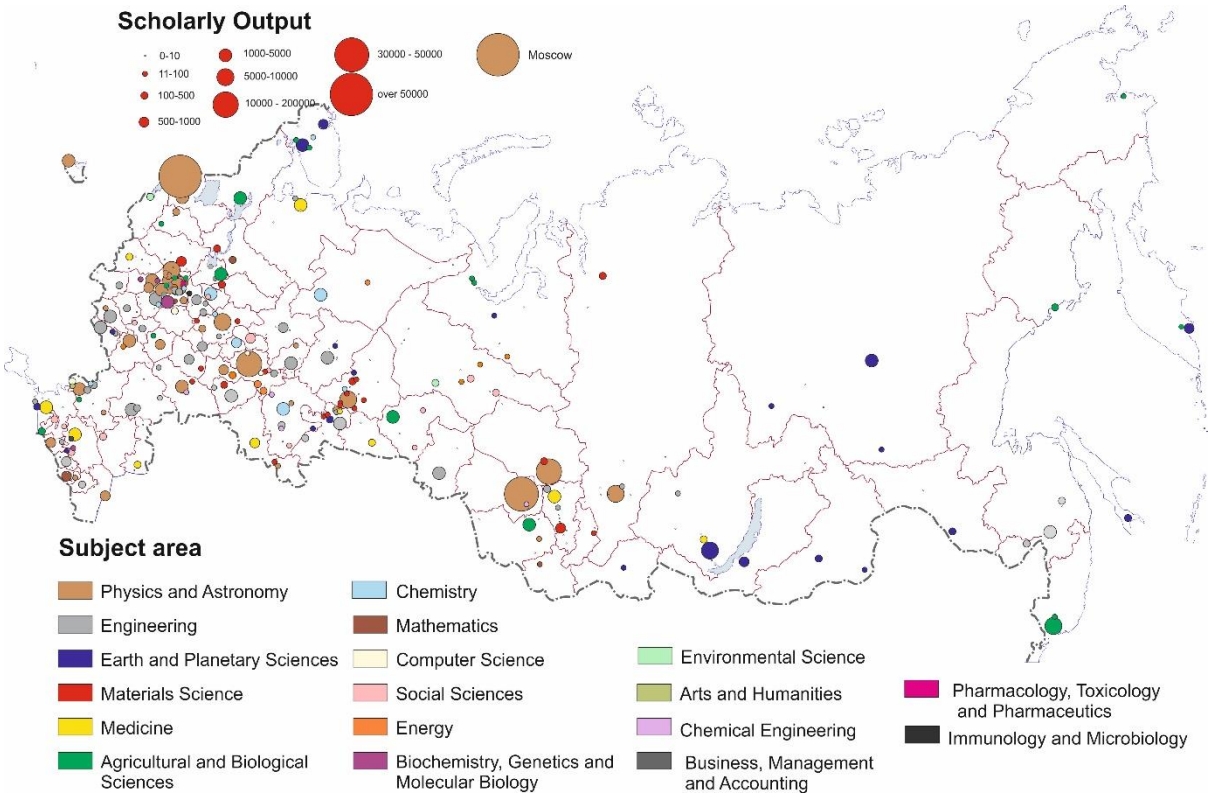
After the meta-data on publications are exported, they are transferred to SciVal analytical toolkit. The Publication Sets are generated per each city and analysed both individually and in benchmarking. In-depth bibliometric assessment includes parameters on the publication volume, citations (incl. field-weighted citations), national and international collaboration, journal quality, and subject areas.

2 Research results

Out of 998 settlements analysed, only 441 feature publications in Scopus database over the period of 2013-2017 (fig. 1). The threshold value for the volume of scholarly output was set at 11 publications minimum, which reduced the sample to 218 cities and 1 rural area.

The total volume of scholarly output is 347,118 papers. By the volume publications indexed in the Scopus database during the five-year period, Russian Federation holds 14th place after the United States, China, the United Kingdom, Germany, India, Japan, France, Italy, Canada, Australia, Spain, South Korea, and Brazil. Analysis of research activity at the level of individual settlements enables us to register the volume of publications made. However, since they are often written in national co-authorship, their sums will exceed the total country level.

Fig. 1: Spatial and thematic distribution of research output across Russia



Source: based on 2013-2017 publications indexed in Scopus.com

As shown in Figure 1, the highest number of publications are written by authors affiliated with the organisations located in the largest cities of the country. Only six cities have over 10,000 publications each: Moscow – 176,419, St. Petersburg – 53,835, Novosibirsk – 34,455, Tomsk – 19,103, Kazan – 14,523, and Yekaterinburg – 11,115. Correlation analysis suggests that there is a strong interdependence between the volume of scholarly output and the number of population registered in a given settlement (the correlation value of 0.96). However, there are numerous exceptions. One the one hand, some large cities with population exceeding 200,000 people have less than 100 papers each: Orsk – 24 publications (0.1 paper per 1000 people), Novorossiysk – 47 publications (0.17 paper per 1000 people), Lyubertsy – 47 publications (0.23 paper per 1000 people), Bratsk – 57 publications (0.25 paper per 1000 people), Leninsk-Kuznetsky – 57 publications (0.59 paper per 1000 people), Balashikha – 62 publications (0.13 paper per 1000 people), Dzerzhinsk – 81 publications (0.35 paper per 1000 people), Nizhnekamsk – 84 publications (0.35 paper per 1000 people), Mytishchi – 88 publications (0.42 paper per 1000 people), Engels – 90 publications (0.40 paper per 1000 people), Stary Oskol – 99 publications (0.44 paper per 1000 people). On the other hand, of 17

settlements with the ratio of papers per 1000 people falling above 10 publications, eight are settlements with under 100,000 people. Of them five are under 50,000 people, including one rural are: Nizhnij arkhyz (rural area in Karachay-Cherkess Republic with an astronomical observatory) – 1324.8 paper per person, Innopolis (a city with a special economic zone for high-tech industry in the Republic of Tatarstan) – 384.3, Chernogolovka (science city in Moscow region) – 254.7, Pushchino (science city in Moscow region) – 125.2, Protvino (science city in Moscow region) – 61.2.

Ranking settlements by the quality of research is done using the Field-Weighted Citation Impact. Results show that only 30 settlements exceed the global average value, including 16 settlements with total population below 100,000 people. These are Innopolis and Yelabuga in the Republic of Tatarstan, Nizhnij arkhyz in Karachay-Cherkess Republic, Borovsk in Kaluga region, Pokrov in Vladimir region, Labytnangi and Salekhard in Yamalo-Nenets Autonomous Okrug, Istra, Protvino, and Dubna in Moscow region, Sibay in the Republic of Bashkortostan, Ozyorsk in Chelyabinsk region, Yurga in Kemerovo region, Gatchina in Leningrad region, Sarov Nizhny Novgorod region, and Tobolskin Tyumen region. These settlements are located in different parts of the country. The diversity is high not only with regard to their geographical location, but also with regard to the subject area ranging from Social sciences to Physics and Astronomy. Overall, settlements located in outlaying regions are characterized by domination of subject areas different from the core knowledge centres, which are Physics and Astronomy – 29.8%, and Engineering – 20.6%.

Table 1 presents data on key scientometric criteria differentiated by the settlement size. The settlements are classified into following groups by population size: under 50,000 people – 32 settlements and a rural area; 50,000 and under 100,000 – 40 cities; 100,000 and under 150,000 – 33 cities; 150,000 and under 200,000 – 19 cities; over 200,000 – 95 cities. The dimensions analyzed are a) the volume of scholarly output, b) Field-Weighted Citation Impact – FWCI, c) Citations per Publication, d) International Collaboration, e) National Collaboration, f) Publications in Top Journal Percentiles (top-10% journals by CiteScore), and g) Subject Area.

Results suggest that settlements size does not affect neither the volume nor the quality of the knowledge domain. Small and average cities are equally productive in the volume of publications, including those issued in top-quality journals; they are well integrated in the national and international knowledge-generation context with the dominance of similar priority research areas. Overall, the correlation coefficient between the population size and the

FWCI value is 0.02, Citations per Publication – 0.04, International Collaboration – 0.07, National Collaboration – 0.06, Publications in top-10 % journals by CiteScore – 0.09.

Tab. 1: Distribution of urban settlements by average values of key scientometric criteria

	Scholarly output	FWCI	Citations per Publication	International Collaboration	National Collaboration	CiteScore 10%	Main subject area
under 50,000							
Median	128	0.51	2.20	0.12	0.22	0.04	Physics and Astronomy
Average	2122	0.63	3.05	0.15	0.23	0.06	
50,000 and under 100,000							
Median	133	0.51	2.20	0.12	0.22	0.04	Physics and Astronomy
Average	2152	0.62	3.01	0.15	0.23	0.05	
100,000 and under 150,000							
Median	152	0.51	2.20	0.12	0.22	0.04	Engineering
Average	2252	0.64	3.08	0.15	0.23	0.06	
150,000 and under 200,000							
Median	132	0.51	2.20	0.12	0.22	0.04	Materials Science
Average	2132	0.66	3.22	0.16	0.23	0.06	
over 200,000							
Median	171	0.51	2.20	0.12	0.22	0.04	Engineering
Average	2308	0.63	3.16	0.14	0.23	0.06	

Source: based on 2013-2017 publications indexed in Scopus.com

3 Discussion

Numerous scholars hypnotize that knowledge and innovation are highly asymmetrical within countries. For instance, Florida et al. (2017) suggests that knowledge tends to concentrate in large cities. Similar to the pattern of industry clusters, knowledge is found to be dependent on the locus (e.g. see: Morgan, 2004). Empirical research around the globe provide insight on the properties and particularities of internal processes that characterize learning regions, living labs, innovative milieu, innovation spaces, etc. The enabling environment required for innovation to occur is hard to achieve and sustain. In this regards, researchers generally advocate for concentrating resources in core cities, as they are the ones naturally generating knowledge and innovation. For instance, Belyaev and Moisburger (2011) discuss on the degree of duties on knowledge generation to be shared with peripheral territories by the capital. This seems to be the common idea in domestic scientific community.

Our study, however, suggests that settlements located in outlying areas can be as productive as the core regions. Smaller cities and even rural areas often excel large agglomerations by not only the quality of research, but also the quantity of scholarly output.

Large cities do not monopolize the role of a global hub or router either. Settlements irrespective of their size are integrated in international collaboration, featuring similar share of publications written in international co-authorship.

Regional higher education and academic institutions are highly important to the knowledge generation domain of the NIS. They ensure integration of science with local industry, public demand, environmental issues, etc. by undertaking place-specific and location-sensitive research.

Conclusion

The discussion on the unequal distribution of knowledge capabilities across national innovation systems is a highly prominent topic nowadays. Since high-tech sector relies on highly sophisticated research (incl. so called mega-science), public authorities consider focusing resources in few innovation cores (clusters, technopoles, technology districts, etc.). Generally, these are a few major cities of the country. The modern facilities created often operate as centres for collective use that provides access to the necessary equipment for regional scholars. Academic mobility programs further support knowledge and technology transfer. Being an ideal scheme on paper, regional knowledge institutions are threatened to be decreased in numbers and size (at least naturally due to reduction in funding). With that, regional innovation systems require strong territorial capital, built on competences of local demand and consisting of institutions able to promptly response to issues arise.

Research results suggest that despite being intangible in nature, knowledge cannot be easily alienated and transferred. Some knowledge is rooted due to environmental factors – mineral resources, landscape, natural reserves, etc., other is dependent on institutional factors, such as manufacturing industries, complementary knowledge institutions of adjacent areas (incl. regions across border). Data on the spatial distribution of research output across Russia by subject area proves this point. The focus of research in the north and east of the country is on exploitation of the rich natural resources (oil, gas, ore, etc.) and marine bio-resources, as well as the ecological issues and the life of indigenous people. Southwestern regions are more oriented on manufacturing industries with clusters mutually reinforcing capabilities.

While there are differences between focus areas, the quality of research is not dependent the settlement size. Small and medium-sized cities are as well efficient in knowledge generation as the large cities are. Coupled with diverse research subject areas, we suggest that availability of excellence centres (HEIs, institutions of the academy of science, other research facilities) at regional level is vital for regional innovation security. The

preliminary assessment of data on spatial scientometrics shows the dependence of values on geo-economic position of a territory, i.e. the proximity to marine and ocean coasts, foreign countries, capital city, large industries, etc. Further research should further investigate these patterns.

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