The Scientific and Technical Clusters in the World Economy

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ABSTRACT: Annotation: *Forming a policy for the scientific and innovative development of the national economy requires an in-depth analysis of development trends in this area, in which Scientific and Technical Clusters (starting now referred to as STCs) play a significant role. The experience of leading countries in patenting and publishing activity, based on the identification of scientific and technological progress, will serve as an example for countries seeking to achieve progress in this area.*

Purpose of the study: *The study was conducted with the aim of analyzing the effectiveness of organizing innovative processes in the aspect of scientific and technical technology, identifying factors and drivers for the development of regional scientific and technological complexes in the global economy, and determining the competitive advantages of leading countries in filing patent applications and publishing activity.*

Data and methods: *Based on the cluster approach used in the methodology of the Global Innovation Index (hereinafter referred to as the GII), the study conducted a comparative analysis of annually published data and GII indicators in the field of patent and publication activity.*

Results: *An analysis of the development of regional scientific and technical technology in the global economy made it possible to identify 20 main scientific areas of scientific and technical technology, the leading positions in which are occupied by medical, digital, and computer technologies, as well as pharmaceuticals.*

As a result of the analysis of patent and publication activity, the leading countries in the STC ranking were identified: the USA, Japan, Germany, and China. Despite the fact that these countries maintained their leadership during the period under review (2017–2021), a decrease in their share (except China) in the total number of analyzed indicators was revealed.

Conclusions: *The possibility of a country's participation in the STC GII ranking is determined by the quality of the fundamental and applied research conducted, which is evidenced in particular by the level of publishing and patenting activity of the* *scientific community. To be included in the STC ranking, the state needs to formulate a scientific and technological policy that would contribute to both improving the quality of research and development and the growth of key performance indicators (the number of patent applications and publication activity).*

Keywords: Scientific And Technical Cluster, Global Innovation Index, Rating, Patent, Scientific Publication, Publication Activity, Competitiveness

Received: 4 January 2023, Revised 7 March 2023, Accepted 21 March 2023

DOI: 10.6025/stm/2023/4/2/57-66

1. Introduction

One of the areas for assessing the innovative development of a country in the world economy, according to the publication of the Global Innovation Index (hereinafter GII) is Scientific and Technical Clusters (hereinafter STC). These are the geographic areas in various parts of the world with the largest number of inventors and authors of scientific publications.The resulting clusters often span multiple municipalities, federal states, and sometimes even two or more countries. The GII publication annually publishes a ranking of the largest STCs in the world (Dutta et al., 2022, 57; 257).

The purpose of our research was to analyze the effectiveness of innovations from the point of view of their geographic concentration, identify factors and drivers for the development of regional scientific and technological complexes in the global economy, and determine the competitive advantages of leading countries in filing patent applications and publishing activity.

To achieve this goal, the following tasks were solved: studying the methodology for forming the STC rating and identifying the main scientific directions of the leading countries in patenting and publishing activity in the world economy.

The results of the study will serve as an information basis for the formation of scientific and technical technology in innovatively active regions. In turn, global recognition of a certain region as a scientific and technological complex will increase the investment attractiveness of this region for subjects of innovative activity.

2. Literature Review

The concept of innovation entered economic theory in the 1930s thanks to the works of J. Schumpeter, who became the founder of the modern theory of innovation. He was the first to consider innovation as the main factor of economic growth and expressed the conviction that production cannot exist without constant changes in technology, the development of new markets, and the transformation of market structures (Schumpeter 1939, 84–85; Schumpeter 1942). The ideas of J. Schumpeter received support in the works of D. Ricardo, who studies the impact of innovation on the economy.

Gradually, innovation became the object of the attention of an increasing number of researchers who developed this concept or enriched it with new content. Thus, according to J. Allen, innovation is the introduction and mass consumption of new products, processes, or ways of behaviour (Allen 1966), and A. Harman considers innovation in the spirit of J. Schumpeter and understands it as the introduction of new or significantly modernized production processes (Harman 1971).

The development of the theory of innovation continues in our time. N.D made a significant contribution to understanding the significance of innovation. Kondratiev, who substantiated the connection between large cycles of market conditions and waves of technical inventions and the duration of their practical use (Kondratiev 2002).

Researchers also note that innovative development must be based on strong institutions and high-quality human capital (Polterovich 2009, 4), while ensuring sustainable economic growth. According to S.V. Kochetkov and O.V. Kochetkova, development can be called innovative if it “provides a qualitative leap in the economic structure of an object while using its innovative potential” (Kochetkov, Kochetkova 2017, 21).

A consequence of the development of the theory of innovation was the theory of clusters. Its development and research in the field of industrial and innovation clusters were carried out by such scientists as H. Schmitz, D. Audrech, M. Feldman, R. Voyer, C. Tiffin, B. Preissl, and others.

Schmitz calls a cluster the sectoral or geographic concentration of enterprises (Schmitz 1995). T. Altenburg and J. Meyer-Stamer understand an industrial cluster as a large agglomeration of firms in a limited area, having a certain specialization profile, and characterized by a significant amount of inter-firm specialization and trade (Altenburg, Meyer-Stamer 1999, 1695).

Among the characteristics of a cluster, these researchers include:

• Positive external results due to the presence of a local reserve of qualified labor and attracting buyers;

• Direct and backward connections between firms within clusters;

• Creating a creative environment and intensive exchange of information between firms, institutions, and individuals in the cluster;

• Joint actions aimed at benefiting from geographical location;

• The presence of a diversified institutional infrastructure that supports the specific activities of the cluster;

• The existence of a sociocultural identity based on common values and the inclusion of local actors in the local environment, which enhances trust in their activities (Altenburg, Meyer-Stamer 1999).

According to R. Voyer, who has studied the topic of clusters for many years as a scientist, policymaker, and promoter of the cluster approach in the private sector, the concept of industrial clustering is very close to the concept of innovation systems since both are about opportunities and relationships (Voyer 1998, 81). In his work, R. Voyer uses the term "innovative industrial cluster" (knowledge-based industrial cluster), by which he means a regional or urban concentration of companies—manufacturers, suppliers, and service providers—in one or more industrial sectors. The activities of these firms are supported by an infrastructure that includes universities and other institutions of higher education, research institutes, financial institutions, incubators, business service providers, and advanced communications/transportation systems (Voyer 1998, 81).

D. Audrech and M. Feldman also point out the close relationships of organizations within the cluster as its key feature. In their works, they define innovation clusters as interconnected organizations that help introduce innovations into certain economic areas or specialties (Audretsch 1995; Audretsch, Feldman 1996).

Thus, an innovation cluster can be considered a type of industrial cluster, the core of which is high-tech or knowledge-intensive companies, while scientific and technological knowledge stimulates the development of new products and the development of enterprises. As noted above, a feature of an innovation cluster is its local limitation. According to S. Tiffin and I. Bortagaray, innovation clusters should be formed within the framework of science parks—administrative structures designed to promote their development (with a focus on the most technologically advanced types of production). Researchers define an innovation cluster as an organizational structure that creates new products and enterprises through collective industrial production in a geographically limited area due to a high concentration of knowledge exchange, interactive learning, and shared social values (Tiffin, Bortagaray 2000). Following R. Voyer, the authors emphasize that a university, a high-tech company, or an incubator are only elements of the cluster, not the cluster itself.

B. Preissl considers the concept of an innovation cluster in a slightly different vein. For her, an innovation cluster is a system of new goods and technologies in a certain economic sphere and at a certain time (Preissl 2003, 27). It is easy to see that B. Preissl leaves out the concept of the geographical limitation of the cluster, its infrastructural elements, and the system of interaction between them. However, the regional nature of an innovation cluster is currently considered by most researchers as its characteristic feature, and when studying innovation, it is the regional factor that often becomes the focus of attention for scientists.

A generalization of the main directions of innovative development and the development of methods for its analysis at the regional level were carried out by D. L. Napolskikh, who proposed a criterion for the optimality of innovative development in innovation clusters in the region (Napolskikh 2019). The works of T. P. Cherkasova and T. R. Ignatova are also devoted to the study of innovation processes at the regional level. They note the archaization of socio-economic relations due to the gradual disappearance of ineffective institutions and their replacement with new ones (Cherkasova, Ignatova 2020). Their study also actualizes the problem of preserving social identity and supporting the competitive advantages of the regional economy in the context of digitalization and proposes promising solutions based on managing the globalization of the region.

G. Surovitskaya, E. Grosheva, and others identify growth points of regional innovation ecosystems that initiate the creation of world-class scientific and educational centers. The authors consider their scientific and personnel potential to be a factor in sustainable regional development. According to researchers, the competitiveness of research and educational centers is determined by the level of development of the scientific and human resources potential of the universities that are part of such centers; therefore, it is essential to develop mechanisms for the effective participation of universities in the activities of world-class research and educational centers and consortia and support these mechanisms based on end-to-end digital technologies (Surovitskaya, Grosheva, 2021).

I. Alekseev, O. Kurilo et al., considering the implementation of the principles of a circular economy from the perspective of sustainable economic development, propose ways to identify and form sources of financing for scientific and technological clusters (Alieksieiev et al., 2022).

K Golçalves, L. Silva et al., assessing the structure of technology transfer in scientific, technical, and innovation institutions, substantiate the importance of formalizing the activities of these centers of technological innovation both for the development of the institutions themselves and for preserving the environment (Golçalves et al., 2023).

An analysis of scientific literature devoted to the consideration of the theoretical foundations of innovation, the principles of the formation and development of innovative activity in the regions, and the study of its economic effect allows us to judge the high importance of the innovation factor for the development of both the national and global economies. Currently, one of the ways to assess the economic efficiency of innovation activity is to look at it through the prism of scientific and technical technology. At the same time, this approach needs theoretical study and understanding. It will contribute to a better understanding of the principles and mechanisms of the functioning of the cluster, as well as its role in the formation of an innovative economy both at the country level and at the level of individual regions. Our research is a step towards solving this problem.

3. Methods and Data

The cluster approach used in the GII methodology allows us to determine innovation performance factors based on geographic concentration and identify the most innovative economies in the world. This can identify the innovation strengths and weaknesses of the countries being assessed and any gaps in their innovation performance.

The geographic boundaries of innovation clusters usually do not correspond to the geographic units for which governments or other organizations collect statistics. STC are formed based on data on geocoded addresses of inventors listed in patent applications of the World Intellectual Property Organization's (WIPO) Patent Cooperation Treaty (PCT) and authors of scientific publications in the field of "science and technology", indexed in the Web of Science database (publications from the field of social and human sciences are ignored).

The names of scientific and technological complexes in the GII are given by the names of one or more cities that form the cluster. The dimensions of the scientific and technological complex are identified on the basis of an empirical approach, which involves several stages. First, the addresses of authors of patents and scientific articles are determined and geocoded, and then an algorithm is applied to the resulting data to map clusters. After geomapping, STCs are identified, and the key characteristics of the top 100 clusters are described.

Initially, clusters were formed based only on patent data, which was the most indicative for assessing the productivity of inventive activity. Since 2018, when compiling the GII and forming the STC ranking, information about the authors of scientific publications contained in the expanded scientific citation index of the Web of Science has been used (Bergquist et al. 2017).

According to GII experts, despite some noticeable changes, the inclusion of data on the authors of scientific publications to identify scientific and technological progress did not fundamentally affect its result or the size of the identified clusters (Bergquist et al. 2017).

Our study of the dynamics of the development of regional science and technology in the world economy is based on a comparative analysis of annually published data and GII indicators in the field of patent and publication activity and is aimed at identifying factors of innovation efficiency and identifying drivers for the development of regional science and technology.

The study was carried out in two stages. The first determined the main scientific directions of the patent performance of scientific and technological complexes in 2017–2020; the second analyzed the patent and publication activity of the leading countries of scientific and technological progress in 2017–2021.

4. Results and Discussion

Analysis of the world ranking of scientific and technological complexes in scientific areas made it possible to identify the dynamics of patent and publication activity in leading countries, as well as to determine the most effective areas of science in the world. In particular, the study identified the main scientific directions of the patent performance of STC in 2017–2020, as well as priority areas of research activity (Table 1).

	STC specialization	**Number of NTC**	
		2017y.	**2020 y.**
	Total	**100**	**100**
1	Medical technology	17	18
2	Digital technologies	16	15
3	Pharmaceuticals	15	15
4	Computer techologies	11	15
5	Transport	7	2
6	Electric cars	7	12
7	Organic chemistry	6	2
8	Chemistry of basic materials	4	4
9	Biotechnology	2	3
10	Engines, pumps, turbines	2	-
11	Civil Engineering	2	4
12	Optics	2	2
13	Semiconductors	4	1
14	Food chemistry	1	1
15	Mechanical elements	1	1
16	Accessories, games	1	-
17	Textile and paper machines	1	-
18	Other special machines	1	-
19	Other consumer products		3
20	Measurement		2

Table 1. Main scientific directions patent performance of STC in 2017-2020

Table 1 shows that out of the 20 main areas of scientific and technical technology, the leader in patent activity for the analyzed period is medical technologies. Leading positions are also occupied by such areas as digital technologies, pharmaceuticals, computer technologies, etc.

By 2020, “accessories, games,” “textile and paper machines,” and “special machines” dropped out of the list of main scientific areas, but new areas appeared—”other consumer goods” and “measurements.” There has been a noticeable decrease in patent activity in areas such as transport, organic chemistry, and semiconductors.

At the same time, the number of scientific and technological complexes in the areas of “electrical machines” and “computer technologies” has increased significantly; the growth in the number of scientific and technical complexes working in the fields of civil engineering and biotechnology is less pronounced. The increase in the number of scientific and technological complexes in the listed areas indicates their high innovative potential and reflects the development trends of the real sector of the world economy.

Summarizing data on patent applications of scientific and technological complexes for 2017–2021 with a calculation of their share of the total number of patent certificates in the world (in%) and the number of scientific and technological complexes made it possible to identify the leading countries in patent activity for the analyzed period (Table 2).

	Countries	**Share (%) of patent applications from the global number (1) and number of scientific and technological innovations (2)**									
		2017 y.		**2018 y.**		**2019 y.**		**2020 y.**		**2021 y.**	
		1	**2**	**1**	**2**	**1**	**2**	**1**	**2**	**1**	**2**
1	USA	28,10	31	16,97	26	16,98	26	16,50	25	15,67	24
2	Japan	25,01	8	15,82	3	15,64	3	16,09	5	16,05	5
3	China	12,15	7	9,14	16	10,67	18	12,36	17	14,17	19
4	Germany	9,35	12	4,30	8	7,72	8	3,98	8	3,93	8
5	Korea	7,56	4	4,87	3	4,93	3	4,90	3	5,16	4
6	France	3,49	5	1,84	3	1,77	3	1,71	3	1,48	2
7	Belgium	1,65	2	1,07	2	1,13	2	1,09	2	1,06	2
8	Great Britain	1,73	3	0,88	4	0,89	4	0,89	4	0,91	4
9	Sweden	1,50	3	0,92	3	0,75	2	0,91	3	0,92	3
10	Canada	1,28	4	0,78	4	0,76	4	0,74	4	0,72	4
11	Switzerland	1,43	3	0,73	3	0,70	3	0,67	3	0,46	2
12	Australia	1,00	3	0,71	4	0,71	4	0,69	4	0,67	4
13	Israel	1,24	2	0,69	1	0,70	1	0,68	1	0,66	1
14	India	0,80	3	0,52	3	0,51	3	0,50	3	0,54	3
15	Netherlands	0,59	2	0,46	1	0,45	1	0,42	1	0,40	1
16	Singapore	0,54	1	0,39	1	0,39	1	0,38	1	0,38	1
17	Spain	0,68	2	0,41	2	0,39	2	0,37	2	0,35	2
18	Italy	0,34	1	0,32	2	0,30	2	0,29	2	0,29	2
19	Denmark	0,47	1	0,28	1	0,29	1	0,28	1	0,28	1
20	Finland	0,54	1	0,31	1	0,28	1	0,27	1	0,25	1
21	Russia	0,34	1	0,23	1	0,21	1	0,20	1	0,18	1
22	Taiwan			0,19	2	0,14	1	0,26	1	0,29	1
23	Turkey			0,14	2	0,28	2	0,30	2	0,32	2
24	Brazil			0,08	1	0,08	1	0,07	1	0,07	1
25	Poland			0,04	1	0,04	1	0,04	1	0,04	1
26	Iran			0,01	1	0,01	1	0,01	1	0,02	1
27	Ireland			0,08	1	0,08	1				
28	Malaysia	0,19	1								

Table 2. Leading countries for S & T patents in 2017-2021 (1-share of patent applications from the global number in the current year (in%), 2-number of scientific and technological complexes)

The indicators in Table 2 indicate that the top three global leaders in patent activity in 2017 were the United States (28.10%), Japan (25.01%), and China (12.15%). In 2021, these countries retained their leadership, but compared to 2017, the indicators for the USA and Japan decreased significantly, while for China, on the contrary, they increased slightly.

In general, during the period under review, a significant decrease in patent activity was observed in countries such as France, Belgium, Canada, Switzerland, Australia, Israel, India, Spain, etc., while in some countries (Belgium, Canada, India, Spain, etc.) the number of STC remains the same, but in others it changes towards a decrease (France, Switzerland, Israel) or even an increase (Australia, Great Britain). At the same time, it should be noted that in several countries over the past four years, the share of patent applications has remained at approximately the same level, showing slight fluctuations in both decrease and increase (Australia, Israel, India, etc.).

An analysis of the publication activity of countries participating in the GII rating shows that out of 27 countries, the largest share of publications comes from the United States, followed by China, Japan, Germany, etc. (Table 3).

	Countries	**Share (%) of scientific publications from the global number (%) and number of scientific and technological progress (2)**							
		2018 y.		**2019 y.**		**2020 y.**		**2021 y.**	
		1	**2**	**1**	**2**	**1**	**2**	**1**	**2**
1	USA	13,77	26	13,31	26	13,08	25	12,55	24
2	China	9,88	16	11,34	18	12,16	17	13,76	19
3	Japan	2,93	3	2,80	3	2,77	4	2,66	5
4	Germany	2,44	8	2,41	8	2,36	8	2,32	8
5	Korea	2,15	3	2,15	3	2,14	3	2,26	4
6	Great Britain	2,14	4	2,16	4	2,09	4	2,04	4
7	Australia	1,84	4	1,80	4	1,79	4	1,82	4
8	France	1,54	3	1,49	3	1,41	3	1,21	2
9	Canada	1,21	3	1,51	4	1,44	4	1,41	4
10	Spain	1,14	2	1,11	2	1,08	2	1,07	2
11	Italy	0,95	2	0,90	2	0,91	2	0,89	2
12	Netherlands	0,97	1	0,94	1	0,91	1	0,88	1
13	India	0,79	3	0,79	3	0,80	3	0,82	3
14	Turkey	0,71	2	0,71	2	0,69	2	0,66	2
15	Iran	0,69	1	0,71	1	0,72	1	0,74	1
16	Switzerland	0,68	3	0,66	3	0,66	3	0,51	2
17	Russia	0,66	1	0,66	1	0,67	1	0,68	1
18	Sweden	0,63	3	0,46	2	0,61	2	0,58	3
19	Singapore	0,53	1	0,54	1	0,53	1	0,52	1
20	Belgium	0,48	2	0,54	2	0,52	2	0,51	2
21	Brazil	0,48	1	0,46	1	0,43	1	0,41	1
22	Israel	0,37	1	0,37	1	0,36	1	0,35	1
23	Denmark	0,32	1	0,32	1	0,31	1	0,3	1
24	Finland	0,21	1	0,20	1	0,20	1	0,19	1
25	Poland	0,28	1	0,28	1	0,28	1	0,28	1
26	Taiwan	0,93	2	0,61	1			0,69	1
27	Ireland	0,25	1	0,25	1				

Table 3. Leading countries in scientific and technological progress in publications in 2018–2021 (1-share of scientific publications from the global number in the current year (in%), 2-number of scientific and technological complexes)

During the analyzed period, the most active growth in the share of scientific publications relative to other countries participating in the rating was observed in China. Therefore, it can be assumed that the increase in the number of clusters in China had a positive effect on publication activity. However, such a result was not observed in other countries. For example, an increase in the number of clusters in Japan did not lead to an increase in the share of scientific publications by Japanese scientists in world science, which may indicate the insufficient activity of Japanese scientific and technological complexes (this conclusion can be extended to other countries demonstrating the same trend). In the USA, France, Switzerland, and other countries, with a decrease in the number of scientific and technical projects, the publication activity of researchers has expectedly decreased.

5. Conclusion

Identification and ranking of STC carried out as part of the preparation of the GII, is one of the areas for determining efficiency in science and innovative development. In the course of our research, aimed at studying the effectiveness of organizing innovative processes in the aspect of scientific and technological complexes and identifying the drivers of innovative regional development, GII data concerning the activities of the first hundred leading scientific and technological complexes in various countries of the world were analyzed in the period from 2017 to 2021.

Firstly, it was found that currently, the most popular scientific areas are medical technologies, digital technologies, pharmaceuticals, and computer technologies. In addition, the following areas have high innovation potential: electrical machines, computer technology, civil engineering, and biotechnology.

Secondly, our analysis of patent and publication activity in different countries of the world in 2017–2021 allowed us to determine the top three countries in the STC ranking: the USA, Japan, and China (Germany occupies fourth place). However, despite maintaining the leading positions of these three by 2021, the shares of patent applications and scientific publications in the global total of the United States and Japan have decreased, while those in China have increased. It appears that China's successes may be associated with an increase in the number of scientific and technological innovations.

Analysis of the GII S&T rating allows us to note the high competitiveness of Chinese S&T globally. Between 2017 and 2018, the number of scientific and technological innovations in China increased sharply (more than doubling) and then slowly grew (Table 2). In addition, it is important to note the growth in the positions of all Chinese science and technology companies in the GII ranking over a short period, both existing ones in 2017 (Nanjing, Hangzhou, Wuhan, Xiang, Chengdu, etc.) and new ones (Qingdao and Chongqing).

The results of the study of the development of regional scientific and technical technology in the world economy can be used to develop national scientific and economic policy. In particular, active reforms in the field of science and innovation currently being carried out in Uzbekistan require a comprehensive analysis of the global scientific and economic situation and best practices. In the future, the data obtained during the study will be in demand when deciding on the possibility of participation of the Republic of Uzbekistan in the STC GII ranking. They will serve as a guide in shaping the agenda for scientific and innovative development of the national economy.

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