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Improving the System of Indicators for Assessing the Effectiveness of Modern Regional Innovation Systems

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Abstract: In the post-pandemic social and economic conditions, the proper assessment of the effectiveness of regional innovation systems (RISs) becomes a key endeavor. In our paper, we highlight the necessity to enhance the set of indicators used to evaluate the performance of regional innovation systems in countries with varying innovation capabilities. Specifically, we concentrate on examining case studies from the United States, Japan, China, and the Czech Republic, comparing their experiences with the current situation to innovations and innovation systems in Russia and drawing lessons for this country. Utilizing the Global Innovation Index (GII) rankings, we conduct an analysis of the characteristics of innovative progress and propose specific groups of indicators that can enhance the effectiveness of evaluating the innovative advancement of different regions. Moreover, we determine the need for uniqueness, flexibility, and adaptability of these based on the state's strategic guidelines in the field of innovation and the innovative potential of the territory as well as the factors of external and internal influence. In addition, we conduct and present the results of the bibliometric network analysis of the research publications retrieved from the Web of Science (WoS) database using VOSViewer software and covering the role of regional innovation systems (RISs) in shaping up the national innovation systems (NISs) both in general terms and specifically applied to the case of Russia. Our results might be relevant for the stakeholders and policymakers who are engaged in promoting innovation, regional development, and sustainable economic growth, as well as for the academics working on the topics of innovation and economic development.

Keywords: innovations; national innovation system; regional innovation systems; indicators; assessment; sustainable economic development

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1. Introduction

In today's highly competitive global economy, innovation has emerged as a key driver of economic growth and development (Etim and Daramola 2020; Ma and Zhu 2022; Kaftan et al. 2023). Recognizing this, governments and policymakers around the world have increasingly focused on fostering regional innovation systems (RISs) to enhance their countries' competitiveness and attract investment (Isaksen et al. 2022; Volchik et al. 2023). Regional innovation systems constitute an integral part of national innovation systems (NISs) (Kolomytseva and Pavlovska 2020; Chung 2002). Distinguishing between regional and national innovation systems is essential for comprehending the complexities of innovation dynamics within any given country (Satalkina and Steiner 2020). While both systems share common elements, they differ in scope, scale, and interplay of actors. Several key differences must be considered when analyzing these systems: (i) geographic scales setting the context; (ii) varying involved actors; (iii) different specialization and innovation clusters; (iv) changing policy frameworks; (v) nuances in knowledge flows and spillovers; and (vi) assorted impacts of global trends and competition. Thence, the dashboard in the

global innovation tracking system is represented by investment in science and innovation, technological progress, and adoption of various technologies, as well as the socio-economic impacts (Park and Choi 2019; Coutinho and Au-Yong-Oliveira 2023).

However, in today's highly globalized and digitalized post-COVID-19 era measuring the effectiveness of RISs and understanding their impact on economic development becomes an increasingly complex task (Song et al. 2022). The evaluation of regional innovation systems is essential for several reasons. It enables policymakers to identify the strengths and weaknesses of their respective regions in terms of innovation capabilities (Firsova et al. 2020). By understanding these factors, policymakers can design targeted strategies to strengthen areas that require improvement while leveraging existing strengths. This approach allows for better resource allocation and more efficient use of public funds to support innovation initiatives (Costa 2021). In addition, evaluating regional innovation systems provides insights into how different components interact within a specific region. Innovation is not an isolated phenomenon but rather a result of various interconnected factors such as research institutions, universities, businesses, government policies, infrastructure, networks, and human capital (Papanastassiou et al. 2020). By assessing these interdependencies comprehensively, policymakers can gain a better understanding of the dynamics within their regions' innovation ecosystems. Furthermore, evaluating regional innovation systems helps benchmark performance against other regions or countries globally (Zemtsov and Kotsemir 2019).

The Global Innovation Index (GII) ratings provide an internationally recognized framework for comparing the innovative capacity and performance across different economies. The GII is an interactive instrument that provides a valuable framework for evaluating regional innovation systems, enabling policymakers, researchers, and businesses to identify strengths, weaknesses, and areas for improvement with a high significance in assessing innovation systems (Kowalska et al. 2018; Dempere et al. 2023; Marti and Puertas 2023). The model of innovation systems presented in the GII offers a holistic approach that considers the multifaceted nature of innovation (Li et al. 2023). By evaluating countries through a diverse set of indicators and dimensions, the GII model provides insights into the strengths, weaknesses, and policy areas that nations can address to enhance their innovation capabilities and drive sustainable economic growth (Mohamed et al. 2022). Thence, the model is particularly relevant in understanding the broader context of innovation, extending beyond research laboratories to encompass economic and social aspects (Piqué et al. 2020). This is due to the fact that it highlights the linkages between science, technology, industry, and policy, showcasing any given nation's innovation skills. Moreover, the GII model underscores the need for adaptability and agility in response to evolving global challenges and opportunities. This is particularly relevant for understanding the broader context of innovation, extending beyond research laboratories to encompass economic and social aspects. It highlights the linkages between science, technology, industry, and policy, showcasing the intricate web that underpins a nation's innovation prowess. The GII model also underscores the need for adaptability and agility in response to evolving global challenges and opportunities (Ben Hassen 2022). Our comprehensive analysis presented in this study will help to allow regions to assess where they stand in relation to their peers in terms of various indicators such as research and development (R&D) expenditure, patent applications, knowledge creation outputs, and technology transfer activities, among others. Furthermore, evaluating regional innovation systems enables policymakers to monitor progress over time by establishing baselines and setting targets for future growth. It helps identify trends or changes that may affect the region's competitiveness in the long run so that appropriate measures can be taken proactively. Finally, understanding the importance of evaluating regional innovation systems also emphasizes inclusivity and equity in economic development. By examining the innovation capabilities of different regions, policymakers can identify potential disparities and address them through targeted policies and initiatives. This ensures that the benefits of innovation-driven economic growth are shared more evenly, reducing regional inequalities.

The main value-added element of this study lies in emphasizing the crucial need to enhance the set of indicators for evaluating regional innovation systems (RISs) in diverse innovation-capable countries. Focusing on case studies from the United States, Japan, China, and the Czech Republic, as well as the lessons they can provide for Russia, we compare their experiences, drawing valuable lessons. Leveraging the Global Innovation Index (GII) rankings, we underscore the importance of uniqueness, flexibility, and adaptability aligned with strategic guidelines, innovation potential, and internal/external influences. Additionally, our study conducts bibliometric network analysis through the VOSViewer software, exploring the role of RISs in shaping national innovation systems (NISs), particularly concerning Russia. The following Research Questions (RQs) are explicitly introduced as the key questions for this study:

RQ1: Should countries with varying innovation capabilities apply enhanced or altered sets of indicators employed for evaluating the performance of their regional innovation systems?

RQ2: What differences between regional and national innovation systems have to be considered in the case of countries described above?

RQ3: What lessons can be learned from the innovation activity of the countries at the top of the GII index by the countries marked by bureaucratic hurdles and the legacy of central planning such as Russia?

This paper is structured as follows: Section 2 offers a comprehensive literature review on papers involving innovation strategies and describes case studies from the United States, Japan, China, and the Czech Republic on one hand and Russia on the other hand. Section 3 discusses tracking innovation and highlights and the role of the Global Innovation Index. Section 4 assesses the innovations and innovative activity in Russia and compares them to the case studies presented in the previous sections. Section 5 reports the results of the network analysis of regional and national innovation systems research based on the bibliometric study. Finally, Section 6 concludes by providing the overall outcomes, policy implications, and pathways for further research.

2. Literature Review

In general terms, the features of the innovation strategies of the countries that affect the indicators for evaluating the effectiveness of their national and regional systems differ in many ways (Wang and Wang 2020; Hintringer et al. 2021; Bruneckienė et al. 2023; or Bobek et al. 2023). For the purposes of this study, we selected four countries (United States, Japan, China, and the Czech Republic) for further comparison and to draw lessons for Russia. The selection was conducted based on their performance and ranking in the GII to ensure better representativeness. Analyzing the effectiveness of RISs in different countries sheds light on the intricate dynamics that influence innovation outcomes and regional competitiveness (Tambosi et al. 2020). The United States, recognized for its longstanding emphasis on innovation, boasts a highly developed RIS characterized by strong linkages between universities, research institutions, and industry. Japan, known for its strong industrial base, emphasizes collaboration between corporations, research institutes, and the government. China's rapid ascent as an innovation powerhouse is marked by its government-driven approach, focusing on large-scale investment in R&D and strategic industries. The Czech Republic, with its small size and open economy, places importance on collaboration between universities, research centers, and the private sector. Russia, with its rich scientific heritage, confronts the task of transforming its legacy R&D institutions into dynamic innovation hubs.

In addition, a comparison of a small economy like the Czech Republic with larger countries like the United States or Japan was conducted due to the fact that it illuminates the role of scale, government support, collaboration dynamics, and talent retention in shaping innovation ecosystems. While small economies may have resource constraints, they can capitalize on proximity, agility, and targeted specialization to foster innovation in specific domains. Such comparisons underscore the importance of tailoring innovation strategies to the unique context of each economy, regardless of its size.

In the United States, innovative development has long been a "national idea", and the strategy of increasing innovation covers all stages of the innovation life cycle, consistently including basic research, applied research, development, and innovation (Tolstykh et al. 2020; Yang and Gu 2021). An important role is played by educational organizations that create a significant number of start-ups with high innovative potential. The main actors of innovation activity in the U.S. are universities, a significant part of which rank high in the world rankings (De Wit 2019; Ebersberger and Kuckertz 2021). Other subjects of the U.S. innovation system are national laboratories and large government institutions that develop certain areas of applied science. In addition, U.S. enterprises influence the direction of scientific research and the educational process, and the state acts as a venture investor and public controller (Birkle et al. 2020; Novikov 2020).

The U.S. innovation system implements the North American model, in which science, business, the state apparatus, civil society, and consumers form a kind of "quintuple spiral", or a network structure of interaction (Pan and Guo 2022). An aspect of the country's approach to innovation is the promotion of innovative endeavors within the private sector, even in the face of potential tactical and strategic setbacks or failure (Petrovsky et al. 2018; Dzigbede et al. 2020).

In the various states of the U.S., at the initiative of the administration, scientific and technological clusters are being created, forming a sort of regional innovation system. The initial capital is allocated from the budget, and further funding is provided at the expense of private investors (Wang and Wang 2019; Firsova et al. 2020; Graf and Menter 2021).

Alongside small enterprises, public–private collaborations are emerging as a fundamental component in shaping the U.S. innovation strategy. Consequently, indicators that gauge the establishment of conducive conditions for fostering long-term relationships between the government and the private sector are incorporated into the evaluation of regional innovation systems' effectiveness (Vecchi et al. 2020; Hagan 2020; Baxter and Casady 2020).

On the other hand, in Japan, a strategy for scientific, technological, and innovative development is being developed by the Council for Science, Technology and Innovation Policy (Tajeddini et al. 2020; Kuzior et al. 2022). The "soft" reform of the national innovation system began with the public sector and then shifted to universities and the business sector. The priorities of the innovation strategy are nanoelectronics and nanomaterials, renewable energy and energy saving, information and communication technologies, biotechnologies, new drugs and regenerative medicine technologies, intelligent robotics, the Internet of Things (IoT), etc. (Klavdienko 2017; Miyashita et al. 2020; Fukuda 2020).

Along with the centralization of R&D management in the public sector, the principles for evaluating state research organizations and scientists were developed and implemented, allowing the distribution of financial resources (salaries, loans, etc.) based on the results of their work. Public sector research institutes and laboratories have greater autonomy in the management of internal resources while maintaining public funding (Cinar et al. 2022).

The proportion of state involvement in innovation development is relatively small, with the majority of budget funds (approximately 95%) being allocated through the public sector to national universities and research institutions (Klavdienko 2017; Borsi 2021). However, the government wields indirect tools to regulate the R&D domain, such as tax incentives, preferential lending, and credit guarantees for small and medium-sized enterprises engaged in research and development activities (Holroyd 2022; Park and Kim 2022; Chang et al. 2022).

It becomes evident that science and education play a significant and essential role in Japan's National Innovation System. In a country with a population of 125.3 million people, there are 604 private, 86 national, and 89 public universities located mostly in large cities that distribute students among themselves by category: national universities that focus on training the personnel for state institutions and organizations, public universities who prepare staff for the municipalities or prefectures, and the private universities that provide cadres for the market (Fukui 2021; Ikegaya and Debbage 2023).

However, Japan faces an issue concerning the collaboration between educational institutions and industrial enterprises in the domain of research and development (R&D).

This challenge stems from the substantial bureaucratic nature of decision-making and the limited interaction between these organizations. The educational establishments possess considerable R&D potential, but they exhibit little inclination toward embracing the outcomes of university research, deeming them incomplete and unsuitable for practical implementation (Ellitan 2020).

Moreover, the lack of incentives for fostering innovation in small and medium-sized enterprises has resulted in a considerable portion of the Japanese population favoring careers in civil service or major corporations. Consequently, this imbalance in the economy has led to a decline in labor productivity. However, Japan continues to focus on technology transfer, and this requires greater activation of flexible indirect methods of economic regulation in order to maintain innovative potential in the regions (Bardhan 2020).

In China, the development of innovation can be divided into fundamental, initial, and catch-up stages, which led to the following positions:

- The introduction of a large number of foreign technologies and domestic developments with higher growth rates compared to their implementation (Guo and Zheng 2019);
- Absorption of basic foreign technologies, attracting foreign scientific and technological talents, encouraging the use of international resources, and improving the policy of attracting foreign investment (You and Xiao 2022);
- Use of various financial means to encourage technological innovation in enterprises (Fang 2022).

China has also significantly increased spending on science and technology, developed a public procurement system, provided financial support to the venture capital market and the development of start-ups, and implemented an effective tax policy in terms of supporting research institutes and other innovation-oriented enterprises (Jonek-Kowalska and Wolniak 2021; Zhou and Wang 2023). At the same time, China faces constraints on crucial technologies imposed by other nations, and there is also a dearth of incentives to drive corporate innovations and foster the growth of scientific and technical talent. These circumstances justify incorporating these factors into the categories of indicators used to evaluate the effectiveness of regional innovation systems (Xu et al. 2023).

When it comes to the Czech Republic, the innovative potential of Czech technology companies has been noted as promising in the recent years (Steruska et al. 2019; Vaníčková and Szczepańska-Woszczyna 2020), having adopted the basic principles established by the governing bodies in the EU in the field of technological development and innovation. In 2020, the Czech Republic saw twenty-one of its companies in the Fast 50 CE ranking of the fastest growing companies in Central and Eastern Europe (Hung 2022). The highest position belongs to the DoDo logistics service, which grew by 8427% in 2020 and managed to take the second place in the ranking (420ON.CZ 2023).

In the second category of the Rising Stars rating, where young companies that have just entered the market are evaluated, Czech companies also became leaders. Of the twenty-five positions, ten were occupied by Czech startups, and seven of them were in the Top-10 (Vávrová 2022). A striking example is the platform for promising traders, FTMO, which provides them with financial capital. Thus, according to this ranking, the Czech Republic is a leader in the field of technological innovation, not only in Central Europe (Kohnová et al. 2019).

However, the country still occupies a weak position in the development of hardware infrastructure. Despite the presence of global multinational companies, the Czech Republic is still lagging behind its competitors in this matter (Rehak et al. 2020). This situation is primarily attributed to the prevalence of risk-averse investors in the Czech investment market and the lack of a network comprising business angels and FFF (friends, family, and fools) category investors who would be willing to fund more daring and high-risk projects (Michiels et al. 2021). Therefore, it is easier for companies to develop software and then look for investors than to first raise capital and only then go into hardware production (420ON.CZ 2023).

However, despite this fact, the Czech Republic remains among the countries with a relatively low number of young technology enterprises per capita, mainly because of the lim-

ited presence of proactive investors. Consequently, to evaluate the performance of regional innovation systems in the Czech Republic, it is essential to incorporate indicators such as the count of young innovators and the proportion of private investment in innovation.

When it comes to Russia, the recent innovative activity in the Russian regions also underwent significant changes. In 2020, it was affected by the coronavirus pandemic, suspending the activities of most enterprises and forcing them to look for new ways to solve production problems, ensure business processes, and use more modern technologies (Zemtsov 2020; Romanova and Ponomareva 2021; Aldieri et al. 2021). However, bureaucratic hurdles and a history of centralized planning pose barriers to the agility needed for an effective RIS (Gurkov et al. 2017).

In Russia, innovation is commonly linked to the introduction of novel products and services into the market. Notably, during the last three years, approximately 68.4% of innovative organizations have successfully undertaken the development of product innovations (Federal State Statistics Service 2023). As a rule, innovations are introduced in high-tech and medium-tech industries (production of aircraft and spacecraft, medical equipment, and vehicles); however, the level of novelty in Russia is much lower than in European countries and is most often focused on products that are already known on the market, but new to organizations. The share of innovative products, fundamentally new for the global market, is only 0.2%, and new products for the sales market of organizations—0.9% (Federal State Statistics Service 2023).

However, in 2022, due to the war in Ukraine, the introduction of economic sanctions and the ban on the imports led to the need to intensify innovation. Meanwhile, it has become crucial to reevaluate the metrics employed for assessing the efficacy of regional innovation systems, wherein elements like the systematic advancement of innovation and the complete lifecycle of innovative products, from their inception to practical implementation in diverse domains, have gained prominence (Panibratov 2021; Zenchenko et al. 2022; Allam et al. 2022).

When looking at the case of Russia, it becomes obvious that the indicators used to evaluate the effectiveness of Regional Innovation Systems (RISs) should encompass the speed of commercializing R&D outcomes and advancements in the information technology (IT) sector, with the aim of swiftly introducing new products and services to global markets (Innovative Development of Russia 2021).

3. Tracking Innovation: The Role of the GII

For over a decade, the Global Innovation Index has provided rankings that monitor the performance of innovation ecosystems in 132 economies and offer insights into current global innovation trends (Menna et al. 2019; Marti and Puertas 2023).

In general, the GII utilizes a range of indicators to evaluate the innovation ecosystem of each country. Each indicator is assigned a specific weight based on its importance in driving innovation. GII ratings are calculated based on a combination of quantitative data from international sources and qualitative assessments from experts in the field (Aytekin et al. 2022). The index assigns scores to each indicator for every country and aggregates them to provide an overall ranking. The higher the score, the better a country's innovation performance (Gurova 2015; Satalkina and Steiner 2020).

Moreover, the GII acts as a policy guidance tool by highlighting policy measures that have been successful in driving innovation in other regions. Policymakers can leverage this information to design targeted interventions and prioritize areas that require immediate attention (Kalenov et al. 2019; Ionescu et al. 2020).

The recent standing of the (Global Innovation Index 2022) for the selected countries is presented in Table 1 below.

When examining the outcomes of the 2022 Global Innovation Index, it becomes evident that the United States advanced to the second spot. Having overtaken France, China came in 11th place, and so far, it is the only middle-income country that is in the top thirty in the

ranking. There is a narrowing gap between North America and Europe and Southeast Asia, and East Asia (Global Innovation Index 2022).

Table 1. Rankings in the Global Innovation Index (2022).

Ranking in the GII	Country	Points	Ranking in Income Group	Regional Ranking
1	Switzerland	64.6	1	1
2	USA	61.8	2	1
3	Sweden	61.6	3	2
4	United Kingdom	59.7	4	3
5	Netherlands	58.0	5	4
6	The Republic of Korea	57.8	6	1
7	Singapore	57.3	7	2
8	Germany	57.2	8	5
9	Finland	56.9	9	6
10	Denmark	55.9	10	7
11	China	55.3	1	3
16	Israel	50.2	15	1
30	Czech Republic	42.8	29	19
37	Turkey	38.1	4	4
40	India	36.6	1	1
47	Russian Federation	34.3	7	30
50	Chile	34.0	40	1
61	South Africa	29.8	14	2

Source: Own results based on Global Innovation Index (2022).

Traditionally, the top 100 science and technology clusters gravitate toward three primary regions—North America, Europe, and Asia—with a notable concentration in China and the United States of America (Gladenkova 2022).

Regarding the Global Innovation Index indicators, the United States of America stands out with the largest number of indicators in two groups—"contribution to innovation" (ninth place) and "results of innovation activity" (sixth place). China secures third place in the "contribution to innovation" group and sixth place in the "results of innovation activity" group. Further along sin this article, we present a more detailed depiction of the (Global Innovation Index 2022) rankings, categorized by calculated groups of indicators (Table 2).

Thus, the United States showed the best results in terms of "Market Development Level" (first place), "Business Development Level" (third place), and "Knowledge and Technology Outcomes" (third place). Europe continues to have the highest number of innovation leaders, with 15 of the top 25 economies. Switzerland has the highest results in the region in the "institutions" position (second in the world) and is a regional and global leader in innovation, ranking first in knowledge and technology results and creative output. Germany is a leader in the field of "human capital and research" (second place), while Sweden dominates in terms of infrastructure and business development (first place in the world in both positions). In addition, seven economies in the Southeast Asia, East Asia, and Oceania region are among the world leaders in innovation.

It should be noted that on a global scale, investment in innovation in 2020–2021 experienced rapid growth due to the coronavirus pandemic. Over 2 years, the number of published scientific articles worldwide has increased significantly, exceeding the mark of 2 million units; in 2020, global investment in R&D increased by 3.2% and the number of international trademark applications increased by 15%; and the number of venture capital transactions increased by 46% in 2021 (Global Innovation Index 2022).

Optimistic but long-term forecasts of experts regarding the development of innovations consider the possibility of the emergence of two innovation waves:

- An innovative wave driven by digital technologies and significantly increasing labor productivity (supercomputing technologies, artificial intelligence, and automation) (Graglia and Huelsen 2020; Bahoo et al. 2023);

- An innovation wave driven by "deep science" and bringing significant changes to health care, food, the environment, and mobility through breakthroughs in biotechnology and nanotechnology, as well as the creation of new materials (Yoruk et al. 2023).

Table 2. Selected metrics for the 2022 Global Innovation Index.

A Country	Overall Ranking in the GII	Institutes	Human Capital and Research	Infrastructure	Market Development Level	Business Development Level	Knowledge and Technology Outcomes	Results of Creative Activity
Switzerland	1	2	4	4	8	7	1	1
USA	2	13	9	19	1	3	3	12
Sweden	3	19	3	1	13	1	2	8
United Kingdom	4	24	6	8	5	22	8	3
Netherlands	5	4	14	14	18	10	5	10
Republic of Korea	6	31	1	13	21	9	10	4
Singapore	7	1	7	11	4	2	13	21
Germany	8	20	2	23	14	19	9	7
Finland	9	11	8	3	17	5	4	18
Denmark	10	9	10	5	15	15	12	14
China	11	42	20	25	12	12	6	11
Israel	16	41	24	42	7	6	7	36
Czech Republic	30	43	33	20	76	28	17	37
Turkey	37	101	41	48	37	47	47	15
India	40	54	43	78	19	54	34	52
Russian Federation	47	89	27	62	48	44	51	48
Chile	50	39	57	47	46	57	54	55
South Africa	61	81	81	77	39	63	56	64

Source: Own results based on Global Innovation Index (2022).

4. Innovations and Innovative Activity in Russia

In Russia, a slight increase (+1.7% compared to 2019) was recorded in the innovative activity of business in the pandemic year of 2020, and the development and implementation of innovations was carried out by 10.8% of large and medium-sized organizations. The most substantial surge in innovation was witnessed in the industrial sector, where innovation activity soared to 16.2%. This remarkable figure indicates a notable increase of 1.1% compared to the data recorded in 2019 (Federal State Statistics Service 2023). In the field of IT technologies and telecommunications, the level of innovative activity was 12.2%, which is 2.4% more than in 2019. In the service sector, the level of innovative activity was 9.8%. The growth of innovative activity in healthcare amounted to 3.3% compared to 2019 and stopped at 8.6%; other growth was measured in areas such as in agriculture—6.6% (2.2% more compared to 2019), in storage and transportation—4% (1.2% more than in 2019), and in construction 3.9% (0.2% more than in 2019) (Vlasova and Roud 2020; Federal State Statistics Service 2023).

As for regional differentiation, in the Volga Federal District, innovative activity was 15.5%; in the Central Federal District—12.5%; in the North-Western Federal District—10.8%; in the Urals Federal District—10.2%; in the Siberian Federal District—9.8%; in the Southern Federal District—8.0%; in the Far Eastern Federal District—6.9%; and in the North Caucasus

Federal District—3.5%. Thus, in 2020, the development and implementation of innovations in Russia was carried out by 10.8% of large and medium-sized organizations. Compared to 2019, the volume of innovative products increased by 5.7% and amounted to 5.2 trillion rubles (Federal State Statistics Service 2023).

Table 3 presents the distribution of organizations that had product and process innovations in 2018–2020 by industry and area of activity (see Vlasova et al. 2022).

Table 3. Distribution of organizations with product and process innovations in Russia between 2018 and 2020.

Types of Innovation	Idustrial Production	Services Sector	Agriculture	Construction	Average by Industry
Product innovation	73.8	65.9	49.8	61.9	68.4
Process innovations:	60.9	67.7	76.0	71.1	65.3
• Processing and communication of information common to the organization	26.2	38.5	27.9	35.2	33.0
• Business management, corporate governance, accounting, and financial accounting	22.1	26.3	23.0	38.6	24.8
• Production and development of goods and services, and maintenance and development of agricultural production	25.9	18.6	59.2	19.0	23.1

Source: Own results based on Vlasova et al. (2022) and Federal State Statistics Service (2023).

Every year, the costs of innovation in large and medium-sized businesses have been growing; in 2020 they amounted to 2.1 trillion rubles. In rubles, growth in constant prices amounted to 8.2% compared to 2019. Most often, innovations are introduced at the own expense of enterprises. The structure of innovation costs are presented in Figure 1.

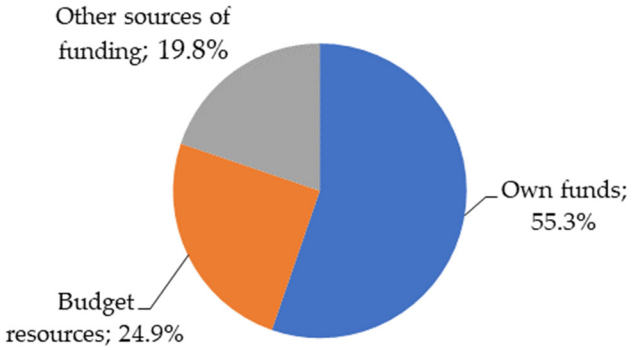

Figure 1. Sources of financing for the introduction of innovations in Russia, %. Source: Federal State Statistics Service (2023).

According to the data depicted in Figure 1, the majority, exceeding 55% of total innovation, is financed through organizations' internal resources. Additionally, close to a quarter of innovations are funded through budgetary allocations, while approximately 20% of innovations are supported via alternative funding sources (Federal State Statistics Service 2023).

The volume and structure of costs for the innovative activities of Russian organizations for 2020 are presented in Figure 2.

In total, 1168.5 billion rubles, or 55% of the total, were invested in innovation in industrial production; in the service sector, investments in innovation amounted to 912.3 billion rubles, or 43% of the total. A total of 39.7 billion rubles were invested in agriculture, or 2% of the total investment, and 13.5 billion rubles were invested in construction, which is less than 1%. The types of innovative activities carried out in 2020 are presented in Figure 3 (Vlasova and Roud 2020; Vlasova et al. 2022).

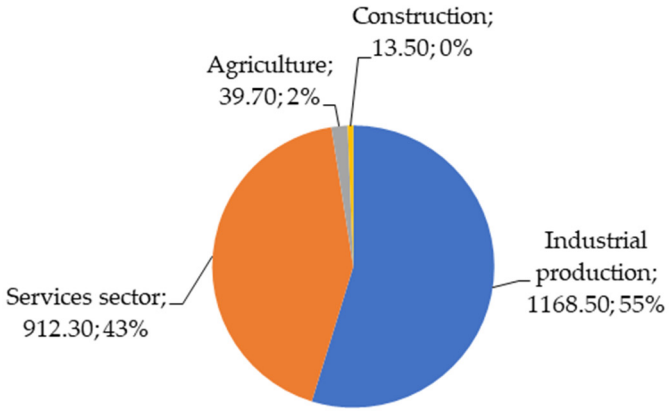

Figure 2. The volume and structure of costs for innovation activities in Russia, billion rubles. Source: Federal State Statistics Service (2023).

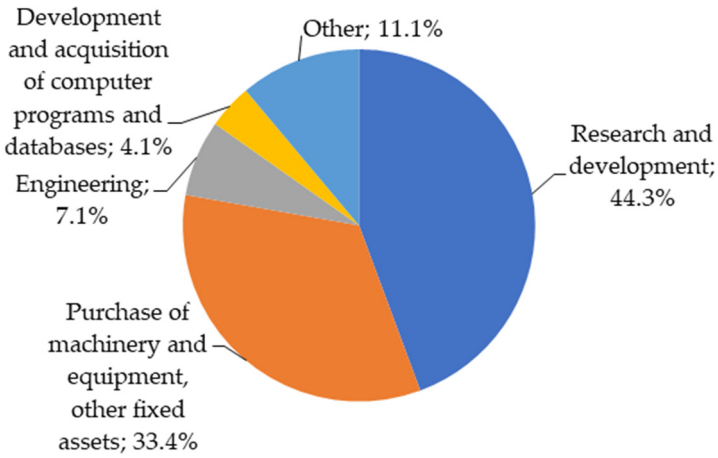

Figure 3. Types of innovation activity in Russia in 2020, %. Source: Federal State Statistics Service (2023).

Out of the overall investment in innovation, 44.3% was allocated to research and development activities, and 33.4% was devoted to acquiring machinery and equipment, along with other fixed assets. A further 7% of the investment was dedicated to engineering, and the development and procurement of computer programs and databases accounted for 4.1% (Federal State Statistics Service 2023).

In comparison with other countries analyzed above, the cooperation in the innovation sphere is not highly developed in Russia—only 28.1% of organizations implementing product and process innovations participated in cooperation relations with external partners. Most often, joint projects were carried out between innovative and scientific organizations (49% of the total); by universities (29.8%); by involving members of their own business group (36.3%); by their own consumers (34.3%); and through involvement of suppliers of materials, components, and software (30.8%). At the same time, only 17% of innovative organizations participated in joint research and development projects in 2020. As part of the implementation of product innovations, 51.1% of companies managed on their own, in process innovations—35.2%. Together with other organizations, product and process innovations were implemented in 28.1% of innovative organizations, product innovations were carried out by other organizations in 31.2% of organizations, and process innovations in 45.4% of organizations (Vlasova and Roud 2020; Rodionov and Velichenkova 2020; Federal State Statistics Service 2023).

Considering the main barriers to the introduction of innovations, one can single out the lack of organization funds (this factor is decisive for 10.6% of innovative organizations, significant for 16.5%) and the high cost of innovations (this factor is decisive for 8.1% of innovative organizations, significant—for 17.6%). Restraining factors lead to the fact that innovation activity is delayed in 5.4% of organizations, stopped in 5%, and not started

in 5.6%. And the innovative potential of Russian organizations at the end of 2020 was low—only 11.2% of organizations planned to carry out innovative activities in 2021–2023 (Zemtsov and Baburin 2020; Federal State Statistics Service 2023).

When assessing the effectiveness of regional innovation systems, the indicators pertaining to technological and innovation sovereignty have garnered significance. Consequently, regional authorities are compelled to establish more conducive environments to foster collaboration between educational institutions and industrial enterprises. This also involves the growth of research laboratories and innovation development centers. For the period 2019–2022, 10 innovative scientific and technological centers were created in the Moscow, Sochi, Primorsky Krai, Tula, Novgorod, Kaluga, Nizhny Novgorod, Kaliningrad, and Ryazan regions. However, their potential is certainly not enough to participate in the development of all regions.

Concerning the significance of education in regional innovation systems, it is imperative to include the extent of innovative education as an additional metric in the evaluation process. This can be calculated by considering the number of educational programs that integrate modules or disciplines related to industrial innovations and innovation development, or by determining the proportion of such programs relative to the total number offered by each higher or secondary vocational education institution.

Furthermore, while evaluating the effectiveness of regional innovation systems, it is essential to incorporate indicators that gauge the level of domestic innovation development and the implementation of these innovations across industries, the service sector, and the social sphere. In conjunction with general innovation indicators, these metrics allow for a comparative analysis, highlighting not only the share of domestic developments but also the ratio of innovations of Russian origin to foreign ones.

In our analysis, emphasis should not solely rely on the number of patents and intellectual property rights registration certificates. Instead, the focus should be on declared innovations by developers, confirmed by the enterprises utilizing them. This comprehensive approach will provide a more accurate and nuanced assessment of the regional innovation system effectiveness.

5. Network Analysis of Regional and National Innovation Systems Research

In this section of our paper, we present the results of the bibliometric network analysis based on the publications describing the links and ties between RISs and NISs. The bibliometric network analysis complements our discussion of the GII by examining the scholarly landscape of RISs and NISs. It identifies linkages and collaborations between researchers, institutions, and industries. Through analyzing co-authorship networks, citation patterns, and keyword trends, it uncovers emerging trends, influential players, and areas of concentrated research activity. In addition, it showcases the intellectual foundations of innovation and highlights the cross-pollination of ideas among academia, industry, and policymakers. Several synergies emerge when linking the GII with the bibliometric network analysis: (i) policy insights validation—the GII's policy guidance can be cross-referenced with bibliometric analysis results to validate the impact of successful policy measures on research output; (ii) feedback loop—insights from bibliometric analysis can provide feedback to policymakers about the research and knowledge dissemination trends resulting from innovation policies; (iii) evidence-based innovation policies—bibliometric analysis can uncover gaps between research outputs and innovation performance; (iv) identifying focal areas—bibliometric analysis can identify emerging trends and areas of expertise in the research landscape; and (v) cross-country learning—by comparing the bibliometric analysis results across countries, regions can identify collaboration patterns and research clusters that contribute to innovation.

We employ the VOSViewer v. 1.6.15 software for that allows establishing of links for the text or bibliometric network analysis using the metadata on the academic publications indexed in research and citation databases. Table 4 provides the summary of data and algorithm for the data selection.

Table 4. Summary of data and data selection algorithm.

Category	Specific Criteria
Reference and citation database	Web of Science
Citation indices	SCI-Expanded, SSCI
Time period	1991–2023
Language	"English"
Keywords	"regional innovation systems" AND "national innovations systems"
Document types:	
Articles	1420
Proceeding papers	418
Others	56
Sample size	N = 1894

Source: Own results.

We have chosen the Web of Science (WoS) database and conducted a search using the terms "regional innovation systems" and "national innovations systems", which retrieved a total number of 1894 indexed publications.

Figure 4 shows the results of the network map based on the text data from the sample of 1894 publications indexed in the WoS database. In total, we were able to identify four main clusters. The analysis of the key words demonstrated that the main clusters related to "regional innovation systems" and "national innovations systems" can be identified with (1) innovation systems and policies; (2) stakeholders and communities; (3) economic development; and (4) direction and formation (see Figure 4).

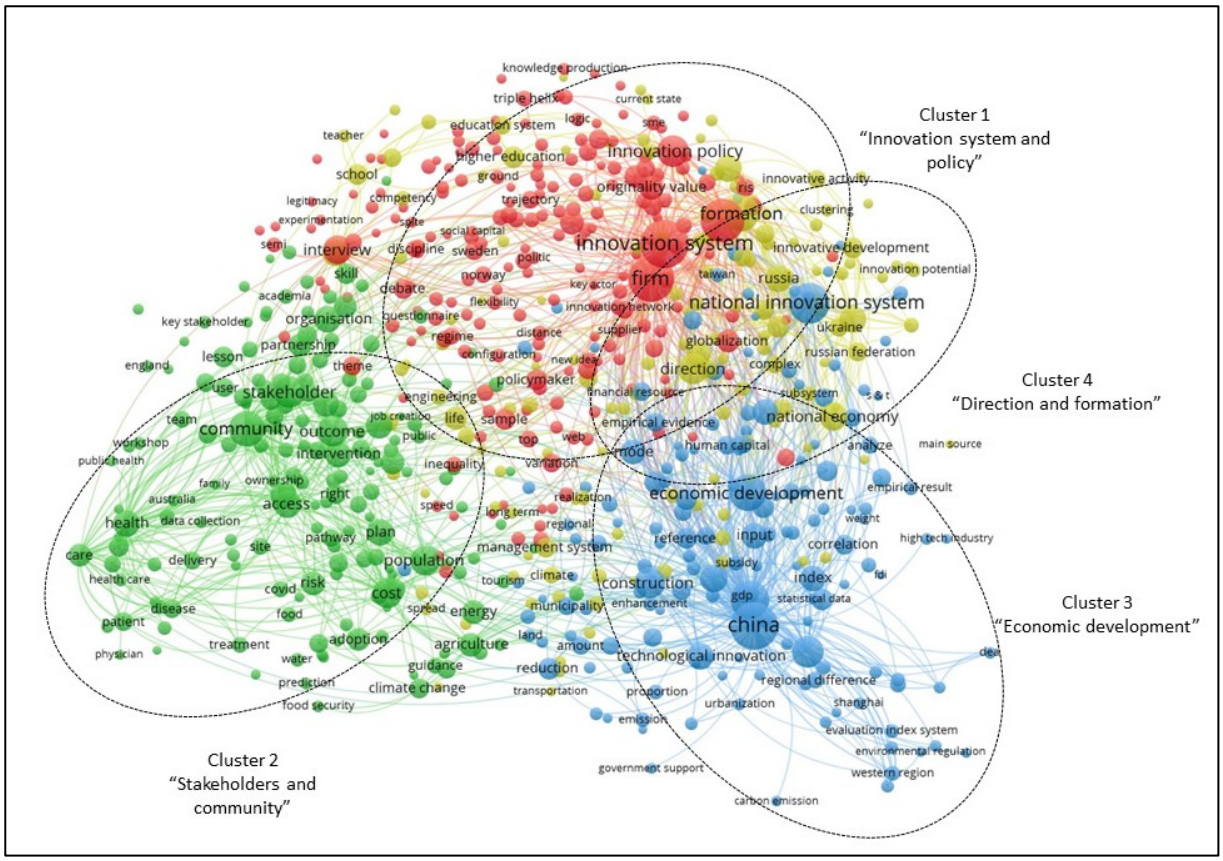

Figure 4. The dominant clusters of cross-sector research connected with "regional innovation systems" and "national innovations systems" from the sample of 1894 publications indexed in WoS. Source: Own results based on VOSViewer v. 1.6.15 software.

In addition, we updated our search and apart from the keywords "regional innovation systems" and "national innovations systems" also included the search term "Russia", which yielded a total number of 89 publications. Figure 5 reports the network map based on the text data similar to the one presented in Figure 4. In this particular case, three main clusters can be identified. They are (1) economic development; (2) implementation and sustainable development; and (3) institutions and innovations (see Figure 5).

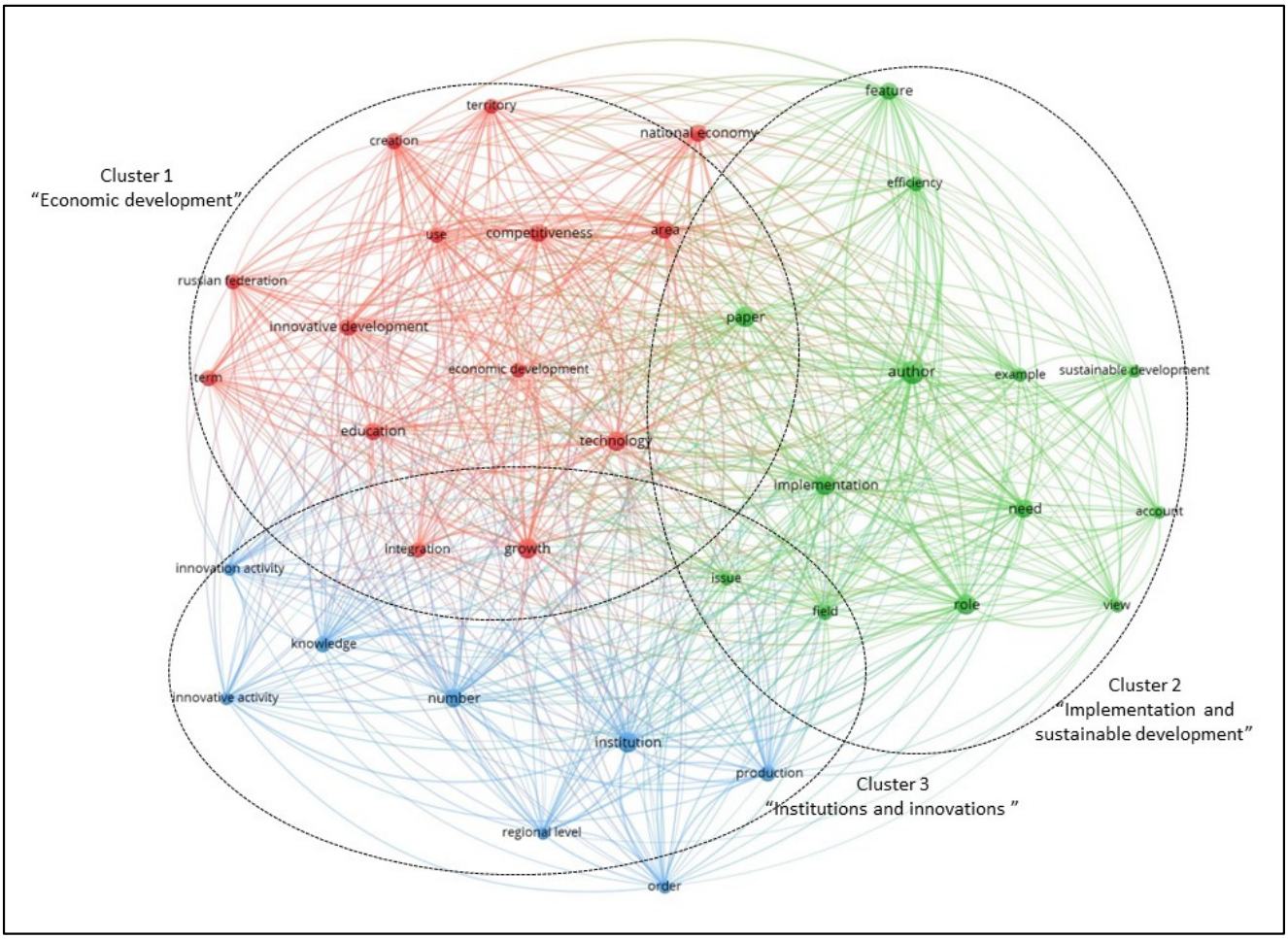

Figure 5. The dominant clusters of cross-sector research connected with "regional innovation systems", "national innovations systems", and "Russia" from the sample of 89 publications indexed in WoS. Source: Own results based on VOSViewer v. 1.6.15 software.

It becomes apparent that the issues associated with the formation of RISs and the NIS in Russia (as described in the relevant literature) are quite similar to those reported in the studies from all over the world (e.g., the emphasis on the role of economic development).

Furthermore, to take our network analysis further and to see the most frequent similarities and differences in the case of Russia and other countries, as presented in the research publications, we conducted an analysis of the bibliographic data. Figure 6 reveals the results of the network map based on the bibliographic data (e.g., keyword co-occurrences, citations, and bibliographic coupling) from 1994 publications containing the keywords "regional innovation systems" and "national innovations systems" and indexed in WoS (Figure 6).

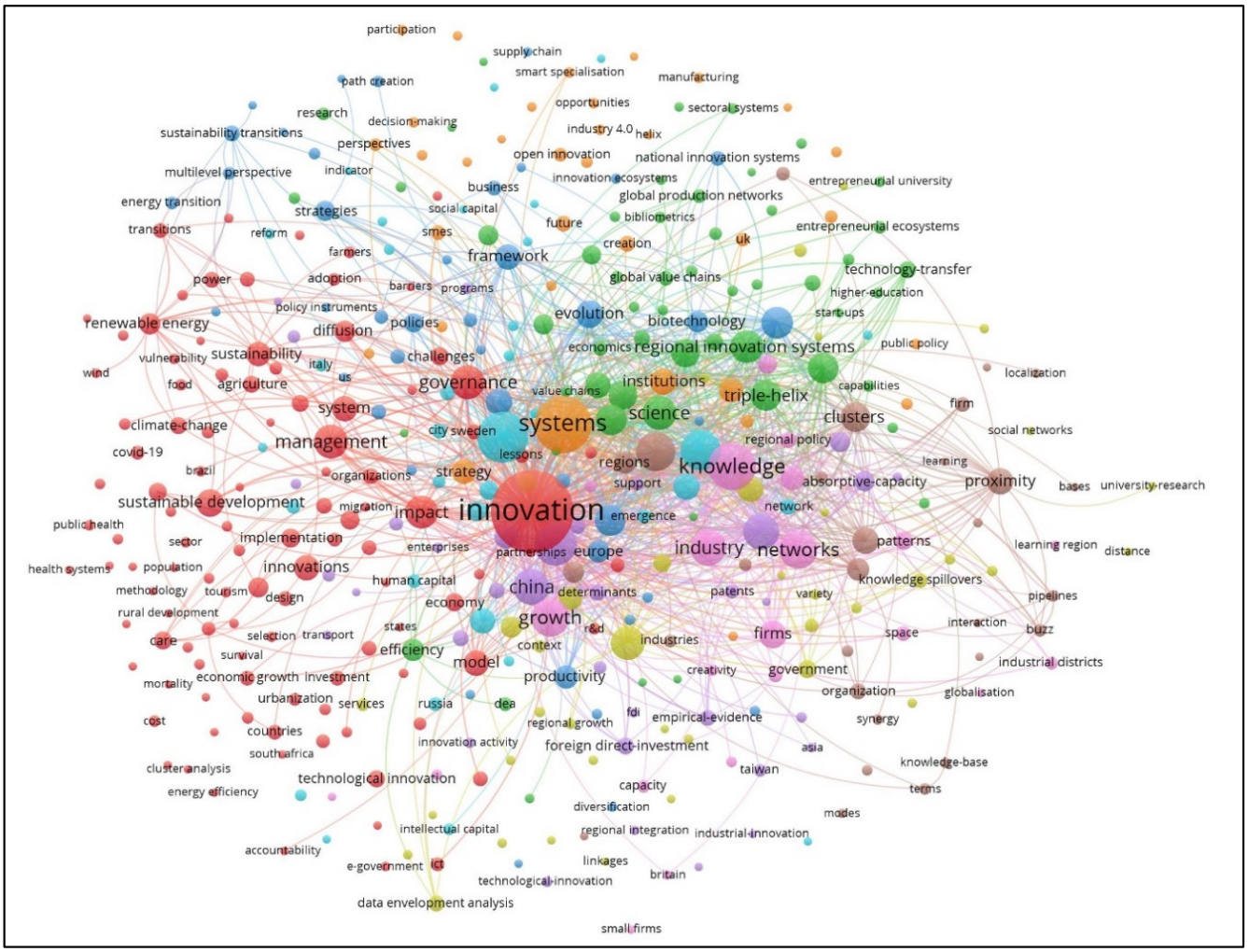

Figure 6. Network map based on the bibliographic data of the sample of publications containing the keywords "regional innovation systems" and "national innovations systems" in 1894 publications retrieved from WoS database. Source: Own results based on VOSViewer v. 1.6.15 software.

Additionally, Figure 7 below reveals the results of the network map based on the bibliographic data (e.g., keyword co-occurrences, citations, and bibliographic coupling) from 89 publications containing the keywords "regional innovation systems", "national innovations systems", and "Russia" and indexed in WoS. From Figure 7, it is clear that when it comes to the analysis of RISs and the NIS in Russia, fewer concepts and concerns are typically mentioned and studied.

Thence, our results show that different approaches might be required for enhancing the effectiveness of evaluating the innovative advancement of different regions for the differences in their RISs and NISs, and it might call for specific measures that are country-related as well as (geo)politically related.

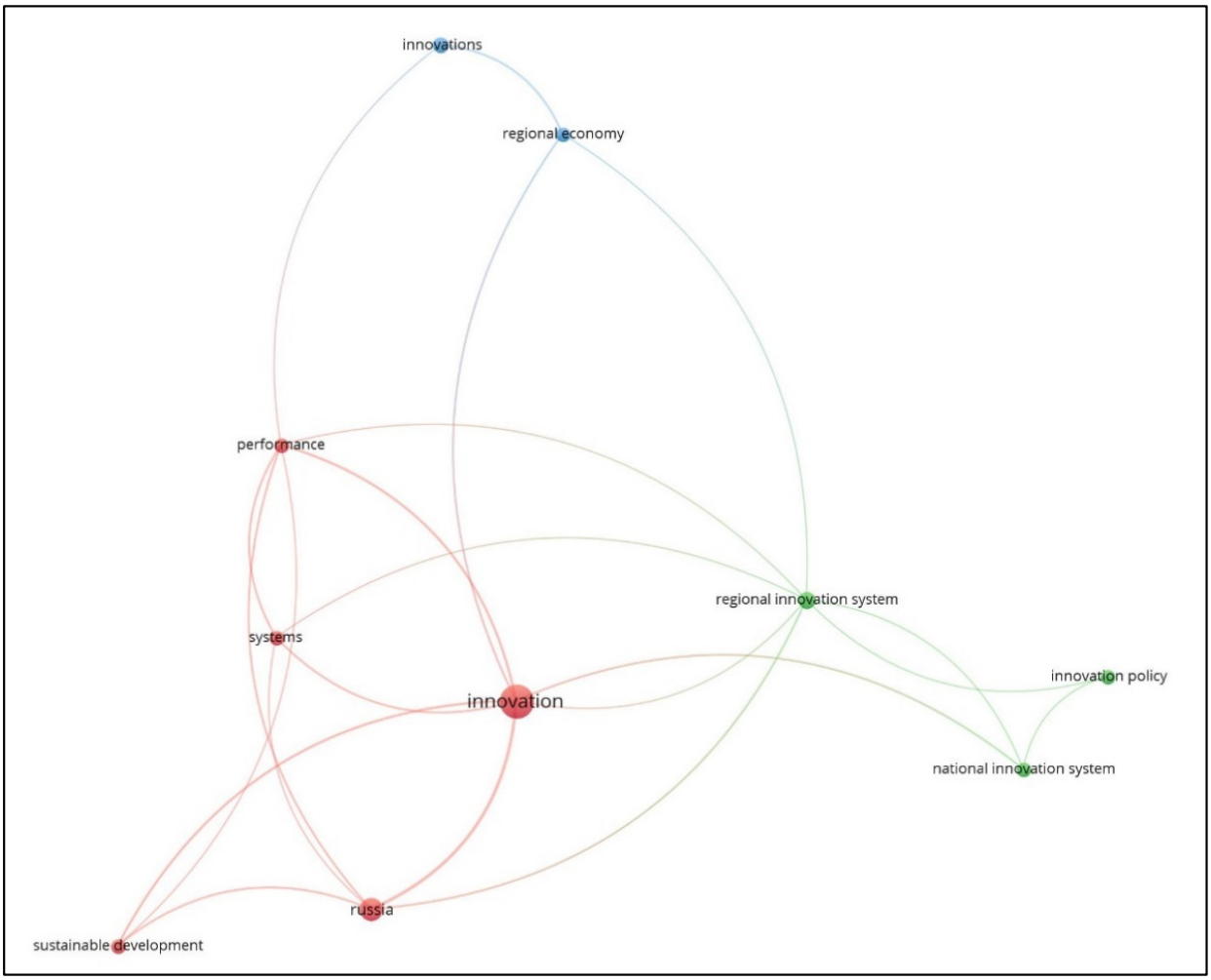

Figure 7. Network map based on the bibliographic data of the sample of papers containing the keywords "regional innovation systems", "national innovations systems", and "Russia" in 89 publications retrieved from WoS database. Source: Own results based on VOSViewer v. 1.6.15 software.

6. Conclusions and Implications

Overall, evaluating regional innovation systems is crucial for understanding their impact on economic development. It provides insights into strengths and weaknesses, interdependencies within the system, benchmarking against global standards, monitoring progress over time, and promoting inclusivity. By conducting a comprehensive analysis using GII ratings, policymakers can make informed decisions to foster innovation-led economic growth in their regions while ensuring equitable distribution of its benefits. The GII serves as a valuable tool in guiding effective innovation policies and initiatives at the national and regional levels. GII results offer a powerful framework for strategic benchmarking and monitoring processes. By leveraging these results, countries can compare their innovation performance, track progress, identify policy priorities, set strategic goals, and advocate for evidence-based policymaking.

We posed three research questions in the Introduction section of this paper regarding the varying innovation capabilities of countries and the application of the enhanced sets of indicators employed for evaluating the performance of their regional innovation systems; the differences between regional and national innovation systems in the case of countries analyzed in our paper; and the lessons that can be learned by such countries as Russia from the innovation activity of the top countries in the GII index. Our results demonstrate that the set of metrics used to assess the effectiveness of regional innovation systems should be adaptable and dynamic, capable of providing real-time data on the

level of innovative development within a territory, and responsive to both internal and external factors of influence. Our analysis, which compared the United States, Japan, China, the Czech Republic on one hand and Russia on the other hand, shows that the approach to building and assessing the innovations might differ in some parameters and focuses. Drawing parallels, the United States and Japan exhibit strong linkages between academia and industry, resulting in prolific innovation. China and Russia, on the other hand, display a degree of state intervention, fostering targeted innovation clusters. The Czech Republic bridges academia and entrepreneurship effectively, although its size impacts the scale of innovation. Moreover, the results of our dynamic network text and bibliometric analysis based on the metadata retrieved from the research publications indexed in the Web of Science database also confirmed the differences that need to be tackled both by the researchers and the policymakers alike.

In addition, the sectorial impact on innovation systems is multifaceted, with each sector contributing uniquely to the innovation ecosystem. Acknowledging the diverse strengths, challenges, and opportunities within sectors is essential for crafting tailored policies that promote innovation, foster collaboration, and drive sustainable economic development. Therefore, the holistic approach that addresses the specific needs of various sectors can create a balanced and resilient innovation landscape.

Through our analysis of various countries with distinct sizes and levels of innovation potential, as well as different innovation development strategies, we found that evaluating the effectiveness of regional innovation systems should be aligned not only with the country's strategic goals and objectives in the innovation sector but also with the prevailing economic and political conditions. In this regard, Russia must prioritize enhancing its technological and innovation sovereignty.

Certainly, the limitations of this study also need to be acknowledged. While the study provides initial insights into RIS effectiveness and innovation capabilities across different countries, its limitations in methodology, contextual analysis, and focus on certain countries weaken the depth and generalizability of the findings. A more robust methodology and a broader comparative approach could enhance the study's contributions to understanding regional innovation systems and their implications for various economies. Moreover, our paper highlights differences in RIS approaches, but it lacks in-depth insights into the contextual factors driving these variations. The discussion merely touches on these differences without delving into the underlying reasons, thereby limiting the practical implications of the findings. It could benefit from a more comprehensive comparison that explores similarities and differences among all analyzed countries. Furthermore, the bibliometric analysis, while insightful, may not capture the full landscape of innovation dynamics. Our study's emphasis on bibliometric analysis from a single database, Web of Science, may exclude valuable data from other sources and hinder a holistic understanding of innovation activities. Nevertheless, we think that our results might provide quite interesting insights into the assessment of the effectiveness of NISs and RISs and generate some food for thought.

Our research highlights the importance of having a flexible and adaptive system of indicators for evaluating regional innovation systems. Further research could focus on developing innovative approaches to continuously update and refine these indicators, ensuring they remain relevant and responsive to changing economic, technological, and political conditions. The results of this study emphasize the significance of contextualizing the evaluation of regional innovation systems based on a country's unique innovation potential, development strategies, and specific socio-economic circumstances. Thence, future research can focus upon the factors that influence the effectiveness of innovation systems in different countries and explore how tailored evaluation criteria can lead to more accurate assessments.

There appears to be a connection between a country's strategic goals in innovation development and the assessment of regional innovation systems. Further studies can

investigate how aligning regional innovation objectives with national innovation priorities can foster better overall innovation performance.

In addition, the lessons stemming for Russia would be to increase its technological and innovation sovereignty, which suggests the need for research on how nations can enhance their indigenous technological capabilities and reduce dependence on external technology and knowledge sources. Russia's journey toward building an effective RIS involves capitalizing on its scientific legacy, overcoming bureaucratic hurdles, fostering cross-sectoral collaboration, and aligning education with industry needs. Lessons drawn from successful innovation models worldwide underscore the significance of agile decision-making, strategic policy reforms, and holistic integration of various stakeholders. As Russia continues to navigate its innovation landscape, the country has an opportunity to channel its scientific heritage into a dynamic and thriving ecosystem that drives sustainable economic growth.

When it comes to the pathways for further research, conducting in-depth comparative studies of various countries' innovation systems can provide valuable insights into best practices, challenges, and strategies for improving innovation performance. Researchers could explore additional countries with diverse innovation experiences to broaden the scope of analysis. Further research could also investigate the long-term impact of using specific indicators to assess regional innovation systems and how policymakers and stakeholders respond to the evaluation results to drive meaningful improvements in innovation policies and practices.

It needs to be stressed that the objectives of regional and national innovation policies are multifaceted and geared toward fostering economic growth, competitiveness, and societal well-being through innovation-driven activities. These policies aim to create an environment that encourages research and development, knowledge creation, technology adoption, and the translation of ideas into marketable products and services. While these objectives remain consistent, the emphasis and strategies might evolve in response to potential de-globalization trends. Historically, innovation policies have been influenced by the advantages of global interconnectedness, including access to international markets, collaboration, and knowledge sharing. However, if de-globalization becomes more important, the objectives of innovation policies may shift to address new challenges and opportunities. Governments might need to recalibrate their policies to foster domestic innovation ecosystems, enhance self-reliance, and adapt to changing economic dynamics. A proactive approach that aligns innovation policies with emerging global realities will be crucial to ensuring sustained progress and resilience in an evolving landscape.

Our findings can have implications for national and regional policymakers not just in Russia but also in other countries and territories in terms of identifying targeted interventions to strengthen their innovative ecosystems. Thus, further research could explore the actual policy implications of the research findings and evaluate their effectiveness in real-world settings.

Overall, there appears to be a need for nuanced and context-specific approaches to evaluating regional innovation systems, considering the unique characteristics and challenges of each country. Further research in these areas can contribute to the development of more effective and tailored strategies to foster innovation-led economic growth and societal development.

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