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Coastal Regions in the Geography of Innovation Activity: A Comparative Assessment of Marine Basins

Andrey Mikhaylov[ABC*], Anna Mikhaylova[B], Daniil Maksimenko[D], Mikhail Maksimenko[D], Dmitry Hvaley[B]

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Abstract

Across the globe marine coasts are experiencing an outstripping growth of the population and economic activity, a phenomenon known as coastalization. Most global cities and industry clusters are located in coastal regions acting as economic growth nodes for their respective countries. This divergence is equally true for national innovation systems, gravitating towards highly urbanized coastal areas. The study is designed to evaluate the spatial stratification of the knowledge production between the coastal regions located in different marine basins – Azov-Black, Caspian, Baltic, Arctic, and Pacific. In order to level-out the national differences of the innovation policy and institutional architecture, the research is held in a single country – the Russian Federation. Our research hypothesis suggests that the knowledge production domain of the innovation activity is influenced by urbanization and coastalization, i.e. the proximity to the core city and the coast. We also expect that the coastalization factor would be reflected in intensified involvement of coastal municipalities in knowledge production networks. The study is based on processing the ROSRID database of 66,647 research projects implemented in 2017-2019 and geocoded using the Yandex.Maps API. The research has shown that the urbanization factor has the strongest influence in configuration of R&D networks – the core centers of knowledge production are the largest cities in marine basins that give further impetus to the involvement of neighboring municipalities. Nearly 70% of municipalities across marine basins have limited or no involvement in the knowledge production, except the Baltic and Azov-Black Sea basins that feature the strongest performance. Overall, the proximity to the coast of non-freezing seas has a positive correlation with the number of R&Ds executed and funded. Considering the research topics, the share of marine-related research is typically funded by coastal regions, whereas the executed R&Ds cover a broad variety of topics. Research results enrich the notion of geography of innovation and advance our understanding of the spatial factors in knowledge distribution within the national innovation system.

Keywords: geography of innovation; knowledge distribution; knowledge production; national innovation system; coastal regions

[A] Institute of Geography of the Russian Academy of Sciences, Moscow, Russia; mikhailov.andrey@yahoo.com; tikhonova.1989@mail.ru; hvaley_gusev@mail.ru
[B] Immanuel Kant Baltic Federal University, Kaliningrad, Russia
[C] Southern Federal University, Rostov-on-Don, Russia
[D] Higher School of Economics, Moscow, Russia. dmaksimenko@hse.ru; mmaksimenko@hse.ru
[*] Corresponding author: Andrey Mikhaylov; e-mail: mikhailov.andrey@yahoo.com

Introduction

The uneven distribution of wealth in the context of the north-south divide, between macro-regions (e.g., Western and Eastern Europe), as well as at the inter- and intra-regional levels within countries is a well-established pattern. Starting with the early foundational research on the spatial configuration of the economy by Walter Christaller, August Lösch, and other prominent scholars, scientists around the world record the existence of central places and their center-peripheral relationships with adjacent territories. As the economy developed and evolved, different elements have been perceived as the nuclei of growth – agriculture (as noted in the Thünen's model), industry (e.g. Weber's theory on spatial economics), and today, the multiple factors behind the knowledge-based economy have come to the fore (Christopherson & Clark, 2007; Švarc & Dabić, 2017). Building on the recent findings of innovation studies (Philipson, 2020), and the geography of innovation in particular (Malecki, 2021), the knowledge production function is the primary element of innovation activity and entrepreneurship, and research and development (R&D) is an important driver of regional growth (Capello & Lenzi, 2013). It must be said that R&D cannot be equated with knowledge, and knowledge with innovation (Capello, 2017), since the generation of knowledge, nor innovation does not necessarily coalesce in space and time (Capello & Lenzi, 2013). However, R&D indicators are being widely used in Science, Technology and Innovation (STI) studies (Schot & Steinmueller, 2018), and the interrelation between entrepreneurs' innovative performance and regional innovation system 'thickness' is proven (Rypestøl & Aarstad, 2018).

In our approach, which relies on the notion of knowledge flows (Sorenson et al., 2006), and their relevance to innovative development and regional growth (Rodríguez-Pose & Crescenzi, 2008), we explore the movement of new knowledge resulting from R&D projects as a basis for innovation activity. In accordance with Asheim & Gertler (2005), we recognize the importance for the generation of new knowledge of a variety of interactions between different actors – firms, organizations in the scientific sector, government agencies. In this regard, the analysis of R&D projects as the basis of a knowledge production system, in our opinion, is of greater interest than, for example, the analysis of patents (Bilbao-Osorio & Rodríguez-Pose, 2004) or publications (Mikhaylov et al., 2020), because funding and execution of R&D involves a wide range of organizations in a triple helix mode. The possibility of geocoding the location of all organizations involved in the knowledge production process and quantifying their contribution to R&D makes it possible to assess the configuration and strength of internal and external links for knowledge production. As noted by Karlsson and Gråsjö (2021) with a reference to Johansson and Lööf (2014), the ability to combine external and internal knowledge positively affects the efficiency of economic agents and their ability to generate new knowledge.

Previous studies held internationally show that the localization of innovation activity is influenced by a number of factors, the main one being proximity to economic agents engaged in the same industry (Karlsson & Gråsjö, 2021). The combination of clustering and agglomeration of territorial innovation models support localized knowledge spillovers. On the one hand, the localization of the knowledge-intensive economy has increased the competitiveness of cities in the accumulation of labor resources and economic activity, on the other hand, it forms new growth nodes that meet the modern requirements of highly qualified personnel and high-tech business – new learning regions. Examples are San Jose, a satellite of Los Angeles, with Silicon Valley as a driver of its development, Innopolis in Russia, a satellite of Kazan, or the Pangio Techno Valley in Korea, a satellite of Seoul. At the same time, according to Pontikakis et al. (2009), more general R&D is effective in core regions, while more specific R&D finds more application in peripheral regions.

The focus of our study is on coastal regions traditionally featuring distinctive patterns in the distribution of economic, settlement and other activities associated with the influence of the coastalisation factor, which has been previously confirmed by Small and Nicholls (2003). It is noteworthy that a significant part of the largest cities and highly developed regions of the world is located in the coastal zone (Cracknell, 1999). In Europe the coastal regions concentrate 42% of the population, generating 43% of the total GRP (Mikhaylov et al., 2018). By studying the increased concentration of people, urban density, industrial clusters, and accumulation of other economic activity in the coastal areas of marine basins, scholars have elaborated on the concept of coastalisation (Mikhaylov et al., 2018). High institutional thickness, a rich variety of interrelated and complementary businesses, as well as the availability of financial, intellectual, and human resources, are argued to be the cause and effect for the development of coastal territories (Anderson, 2005; Merk et al., 2013). Based on the factors of the territorial capital of coastal territories, various territorial innovation systems are being formed here, which are of-

ten mentioned as best practices in the implementation of the transition strategy to a knowledge-based economy (e.g. Witte et al., 2018).

The purpose of the study is to assess the spatial stratification of innovation activity between coastal regions located in different sea basins – the Baltic, Caspian, Azov-Black, Arctic, and Pacific. The following hypotheses were tested in this study: 1) at the regional level, the innovative activity gravitates towards the nodes of the national space – the core cities; 2) at the municipal level in coastal regions, along with the urbanization factor, the knowledge flows are expected to be influenced by the coastalisation factor, localizing near the coast.

Data and methods

Research area

The study covers all coastal regions of Russia – a country often perceived as 'a sea of land' (i.e. a huge land mass) but actually having a total coastline of 46,000 km, facing 3 oceans and 13 seas. Regions are attributed to the coastal type by having some coastline (a direct access to the sea or ocean). Of the 85 regions in total, 23 are coastal, dominated by the Arctic basin – 30.4% and the Pacific basin – 26.1%. On the Atlantic side, two basins are distinguished – the Baltic basin and the Azov-Black basin, comparable to the Arctic basin by the number of regions.

The study was implemented on two levels – regional and municipal, including the inner districts of large cities. Out of 2,398 municipalities, 547 (22.8%) are part of the coastal regions. The detailed breakdown of the coastal regions shows that 33.3% of municipalities have direct access to the sea (Table 1).

Research data

Data on the knowledge production is sourced from the ROSRID database of the Center of Information Technologies and Systems for Executive Power Authorities (CITIS), which provides an overview of all R&D projects and the results of intellectual activity in Russia. The data covers reports on 66,647 projects of 2017-19. The dataset includes project name, keywords, OECD fields of science and technology classifications (FOS), funding volume by source, and the list of contractors.

Data on the location of R&D contractors and customers was sourced from the SPARK-Interfax database by linking the organization name to the tax number in the State Register of Legal Entities. The addresses of legal entities were geocoded using the Yandex.Maps geocoder API in the geopy 2.2.0 Python package and aggregated at the municipality level. Population data was obtained from the statistical database of Rosstat as of the most recent year available (January 2021-2022).

Data on the proximity of the municipality to the coast and the core city of the basin were obtained by geoinformation calculations using the built-in modules of the QGIS 3.14 program. The proximity to the core city is the distance from the geometric center of the municipality to the nearest city that acts as the core in the basin (this might not coincide with the administrative center of the region that the municipality belongs to). St. Petersburg and Kaliningrad were singled out as core cities for the Baltic basin; for the Caspian basin – Astrakhan and Makhachkala; Azov-Black basin – Rostov, Krasnodar, Simferopol, and Sevastopol; for the Arctic – Krasnoyarsk, Arkhangelsk, Yakutsk, Murmansk, Petrozavodsk, Novy Urengoy, and Noril-

Table 1. Geography of the study by marine basins

Marine basin	Coastal regions		Municipalities	
	No.	Name	No.	Coastal, %
Azov-Black Sea	4	Krasnodar Krai, Rostov Oblast, Republic of Crimea, Sevastopol	136	31.6
Caspian Sea	3	Astrakhan Oblast, Republic of Dagestan, Republic of Kalmykia	78	21.8
Baltic Sea	3	Kaliningrad Oblast, Leningrad Oblast, St. Petersburg	59	52.5
Arctic	7	Arkhangelsk Oblast, Nenets Autonomous Okrug, Murmansk Oblast, Republic of Karelia, Republic of Sakha (Yakutia), Krasnoyarsk Krai, Yamalo-Nenets Autonomous Okrug	173	18.5
Pacific	6	Kamchatka Krai, Magadan Oblast, Primorsky Krai, Sakhalin Oblast, Khabarovsk Krai, Chukotka Autonomous Okrug	101	58.4
Total	23	–	547	33.3

sk; for the Pacific – Anadyr, Vladivostok, Magadan, Petropavlovsk-Kamchatsky, Khabarovsk, and Yuzhno-Sakhalinsk.

Research procedure

There are two levels of study: regional and municipal. At the regional level, the indicator weights and territorial connectivity of marine basins and individual coastal regions was assessed in relation to knowledge production. Two blocks of indicators were analyzed: 1) R&D execution: the number of contractors in total and per region, the number of completed projects and their funding, the number of R&D customer organizations (internal and external); 2) R&D funding: the number and volume of projects funded, average project size.

Special attention is paid to assessing the influence of the factor of proximity to the sea on executed and funded R&D, highlighting the share of marine-related research. To do this, an analysis was made of the titles, keywords, and FOS of R&D projects with the emphasis on marine and maritime topics. Also, among the over 160,000 unique keywords and phrases attributed to distinctive projects, 1,063 were related to the sea (containing "marine-", "fish-", etc.). Overall, 20 coastal regions and 48 municipalities were involved in marine-related research.

At the municipal level, the divide of outgoing and incoming knowledge flows was assessed as a result of the cross-effects of proximity to the core city, the degree of urbanization, and proximity to the coast.

Research results

Regional projection of knowledge flows

Moscow is the hub of national knowledge production. The capital city accounted for 89.8% of funded and 66.7% of executed R&D, featuring the highest average funding volume per project among other regions – 0.24 million USD (14.9 mln rubles). In coastal regions, R&D funding amounted to 1.02 billion USD (63 billion rubles) – almost half that of inland regions (or 5.9 times including Moscow). By the number of R&D projects, the coastal regions are also half that of inland regions (excluding Moscow), and by the number of contractors – more than 2.2 times lower, with the average number of contractors – 22 vs. 34. However, the average project size is somewhat larger: 72.7 thousand USD (4.5 mln rubles) in coastal, and 69.5 thousand USD (4.3 mln rubles) in inland regions. There is a strong differentiation of coastal regions in knowledge production by marine basins (Table 2).

The second largest knowledge production center is St. Petersburg, part of the Baltic Sea basin. This explains its high share by the concentration of contractors (55%), the number (51.5%) and volume (56.7%) of R&D registered. Second is the Azov-Black Sea basin, where the city of Rostov-on-Don is the core. In third place is the Arctic basin with Krasnoyarsk being the core city. The Caspian basin regions have the smallest contribution – about 6% of contractors and 3% of R&D, and the polarization of the innovation space is around Makhachkala.

By the average R&D contractors' density per coastal region (excluding St. Petersburg, as due to its weight, it greatly distorts the distribution), the highest values are in the regions of the Azov-Black Sea basin – 40 institutions per region, which also surpass the inland regions (34 per region). In the other four basins, the values are below the inland regions. Most modest values are of the Pacific basin – 15 contractors per re-

Table 2. R&D performed in coastal regions of Russia by marine basins, 2017-19

Marine basin	Contractor		R&D projects		
	Total	Regional average	No.	Volume, mln USD	Average R&D cost, thousand USD
Azov-Black Sea	161	40	3,008	161.0	53.3
Caspian Sea	59	20	456	35.6	77.5
Baltic Sea	522	29*	7,201	575.2	61.4*
Including Saint Petersburg	464	464	6,855	553.9	80.8
Arctic	117	17	1,899	136.5	72.7
Pacific	90	15	1,407	106.5	75.9
Supplementary					
Inland regions	3,514	34*	52,677	7,891.6	69.5*
Including Moscow	1,457	1,457	24,588	5,937.3	240.7

*Note: * excluding Moscow, St. Petersburg*

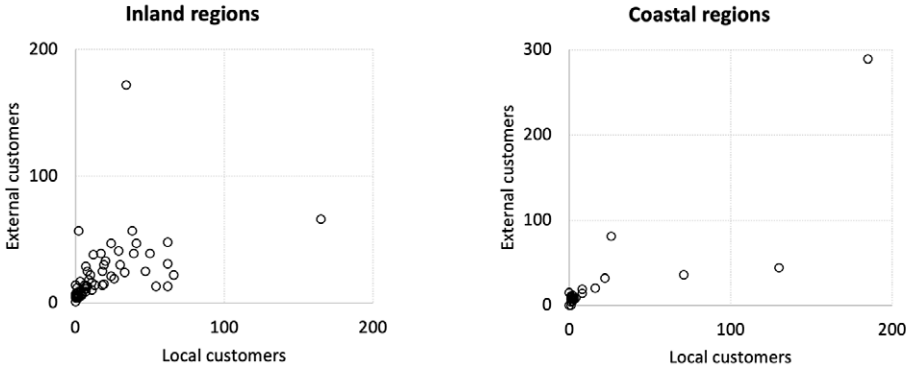

Figure 1. Distribution of regions by location of organizations that finance R&D

gion. Most regions facing the Pacific Ocean (Magadan Oblast, Sakhalin Oblast, Chukotka Autonomous Okrug, Kamchatka Krai) are poorly involved in the knowledge production system having a much smaller number of R&D contractors than the two leading regions – Primorsky Krai and Khabarovsk Krai. By the level of funding, on average, the largest projects are implemented (besides St. Petersburg) in the regions of the Caspian and Pacific basins, and the smallest – in the regions of the Azov-Black basin. Organizations that finance R&D in the coastal regions are located both within coastal areas and outside – in the inland regions, primarily in Moscow (Figure 1).

The correlation coefficient between the number of external and internal R&D customers for the coastal regions (excluding St. Petersburg) showed a noticeable positive relationship (equal to 0.588) – a probability of 95%; variability index is 34.6%. For the inland regions (excluding Moscow), a similar calculation showed a much smaller mutual dependence, the relationship of 0.457.

In the Azov-Black basin, a significant part of R&D customers is domestic, concentrated in its coastal regions. Thus, for R&D performed in the Rostov Oblast, customers were 3 times more likely to be located within the region: 130 vs. 44. Similarly for the Krasnodar Krai, the gap is twofold – 71 vs. 36. Localization of customers and contractors within the same region aligns research topics to the interests of regional development, covering the demand of local organizations. R&D in Sevastopol and the Republic of Crimea is still largely funded from other Russian regions. However, the number of domestic customers in Crimea (22 organizations) is higher than in most other coastal regions.

The regions of other marine basins (except St. Petersburg) are significantly inferior to the Azov-Black basin both in terms of the total number of R&D customers and by the internal/external ratio, with the latter prevailing. St. Petersburg has the dominance of external customers by 1.6 times; however, their total number (474 organizations) outlines the city as one of the largest cores of the national knowledge production system, satisfying not only external, but also their own demand. Table 3 reflects the relationship between the coastal regions of marine basins and inland territories by knowledge production.

Regions of the marine basins primarily act as contractors rather than funders. This is seen from the multiple excess of R&D performed over funded, both

Table 3. R&D funded by the coastal regions by marine basins, 2017-19

Marine basin	R&D funded from outside the region			Completed/funded R&D ratio	
	No.	Volume, mln USD	Average volume, thousand USD	By number	By volume
Azov-Black Sea	176	4.0	22.6	17.1	40.7
Caspian Sea	19	0.7	37.2	24.0	50.1
Baltic Sea	317	13.5	42.0	22.7	42.6
Including Saint Petersburg	263	12.6	48.5	26.1	43.9
Arctic	152	3.5	22.6	12.5	39.2
Pacific	66	3.6	54.9	21.3	29.3
Supplementary					
Inland regions	35,744	3,079.3	85.6	1.5	2.6
Including Moscow	31,348	2,787.2	88.9	0.8	2.1

in quantity and volume. For inland regions, this gap remains modest. The dominance of R&D funded over completed is typical only for Moscow, since the capital hosts the majority of organizations that finance R&D. There is also difference between the average funding per project – expensive projects are, generally, held in coastal regions.

Excluding the absolute leader St. Petersburg, the largest volume (by amount) of external R&D was funded by the regions of the Azov-Black, Pacific, and Arctic basins. With that, while in the case of the Azov-Black and Arctic basins, the average project size fluctuated at the level of 22.6 thousand USD (1.4 mln rubles), the regions of the Pacific basin had larger projects – on average, 54.9 thousand USD (3.4 mln rubles) each. The impact of coastalization on the knowledge production was assessed by evaluating the share of marine-focused R&D (Table 4).

Table 4. Coastalization factor on the R&D focus in the regions of marine basins, 2017-19

Marine basin	Marine-related R&D, mln USD		Share of marine-related R&D in total volume, %	
	contractor	customer	contractor	customer
Azov-Black Sea	15.15	1.94	9.4	49.0
Caspian Sea	1.46	0.03	4.1	4.0
Baltic Sea	22.64	3.58	3.9	26.4
Including Saint Petersburg	21.75	3.43	3.9	27.2
Arctic	11.63	0.10	8.5	2.9
Pacific	17.81	0.43	16.7	11.7

R&D held in coastal regions, generally, had a broader agenda. The share of marine-related R&D in the Azov-Black and Arctic basins did not exceed 10%, and for the Baltic and Caspian basins – 5%. The exception is the regions of the Pacific Basin, where 16.7% of marine R&D was registered. In relation to R&D commissioned outside, the share of marine topics is significant for the Azov-Black and Baltic basins. The lowest demand is from the regions of the Caspian Basin and the Arctic (less than 5%).

Municipal projection of knowledge flows

This section is devoted to the analysis of center-peripheral and coastal patterns of knowledge flows at the municipal level in the context of marine basins. Table 5 presents the coefficients of paired correlation for the entire array of municipalities in coastal regions for R&D funded/executed and such parameters as population, distance from the core city and the coast.

The strongest relationship is between the number of R&D executed and the population size (0.601). Organizations performing R&D tend to be located in populous municipalities. The factor of spatial proximity to a large core city or the coast is less significant. There are also differences between marine basins. For the Baltic Sea basin, the proximity to the core cities (St. Petersburg and Kaliningrad) and the coast turned out to be a significant factor influencing the volume and amount of R&D performed. In second place is the Azov-Black basin, which has a tripolar system for knowledge production, including the core cities – Rostov-on-Don, Krasnodar, Simferopol-Sevastopol. For the Arctic basin, high executed R&D is typical for municipalities that are remote from the coast and is strongly associated with the settlement system. Also, a very strong positive relationship between the executed/funded R&D and the population size is typical for the Caspian basin.

Figures 2-4 present a typology of municipalities in coastal regions by the ratio of executed/funded R&D. In the Azov-Black basin, as well as the Baltic one, over half of the municipalities are involved in the knowledge production – a high result compared to other marine basins (Fig. 2). About 32% Azov-Black basin municipalities are predominantly consumers – R&D is held in 23% of municipalities, primarily, in Rostov-on-Don, Krasnodar, Sevastopol, Yalta, Novocherkassk, and the Simferopol area.

The neighboring Caspian basin, in contrast, is significantly inferior not only to the Azov-Black, but also to other basins by its involvement in knowledge production (Fig. 2). Over 88% of the Caspian municipalities did not execute/fund R&D. Only 9 municipalities executed R&D, led by Astrakhan in the Astrakhan Oblast, Makhachkala in the Republic of Dagestan and, to a lesser extent, Elista in the Republic of Kalmykia.

The Baltic Sea basin has a high rate of involvement in the knowledge production – over 59% municipalities, with the core role of St. Petersburg. All three groups are diversely represented: Predominantly producers (35.6%), Miscellaneous (3.4%), Predominantly consumers (20.3%). The regions of the Arctic basin are stretched from west to east and north to south of Russia, making this basin diverse in R&D conditions. Over 75% of the municipalities of this basin are classified as not involved in knowledge production, another 16%

Table 5. Correlation coefficients between for municipalities of coastal regions

Indicators	R&D executed		R&D funded	
	Value	Number	Value	Number
All municipalities				
Proximity to core city	-0.164	-0.179	-0.106	-0.171
Proximity to the coast	-0.074	-0.068	-0.050	-0.073
Population size	0.457	0.601	0.245	0.566
Azov-Black Sea basin				
Proximity to core city	-0.237	-0.245	-0.218	-0.135
Proximity to the coast	-0.138	-0.121	-0.146	-0.135
Population size	0.613	0.804	0.682	0.723
Caspian Sea basin				
Proximity to core city	-0.130	-0.185	-0.196	-0.223
Proximity to the coast	-0.067	-0.078	-0.049	-0.085
Population size	0.885	0.945	0.834	0.908
Baltic Sea basin				
Proximity to core city	-0.313	-0.354	-0.231	-0.311
Proximity to the coast	-0.212	-0.238	-0.159	-0.209
Population size	0.273	0.304	0.107	0.258
Arctic basin				
Proximity to core city	-0.190	-0.162	-0.127	-0.159
Proximity to the coast	-0.015	0.032	0.076	0.014
Population size	0.882	0.954	0.663	0.909
Pacific basin				
Proximity to core city	-0.239	-0.234	-0.215	-0.218
Proximity to the coast	-0.065	-0.052	-0.015	-0.026
Population size	0.776	0.800	0.774	0.742

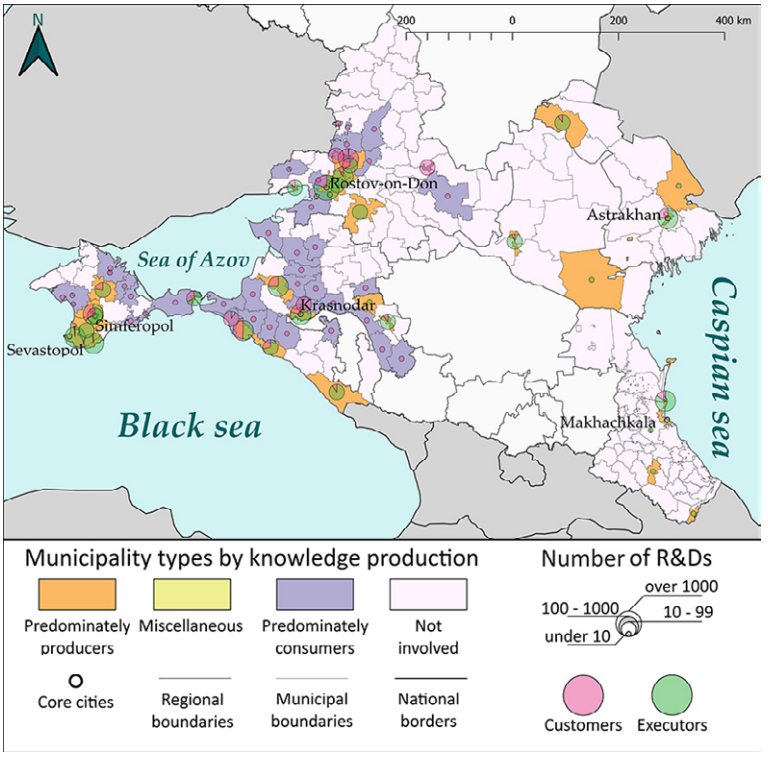

Figure 2. Typology of municipalities in the Azov-Black Sea and Caspian Sea basins for knowledge production

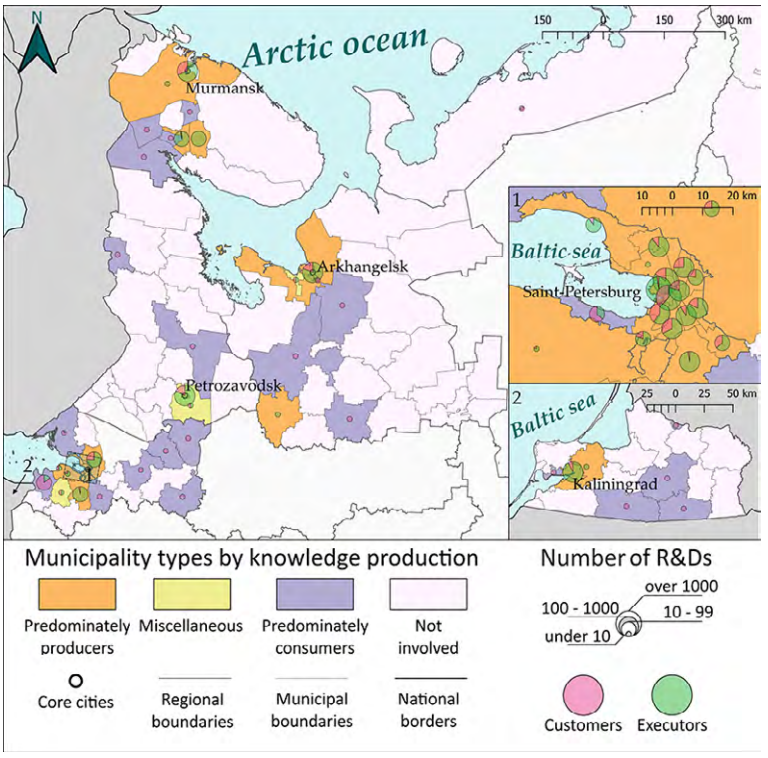

Figure 3. Typology of municipalities in the Baltic and Western Arctic basins for knowledge production

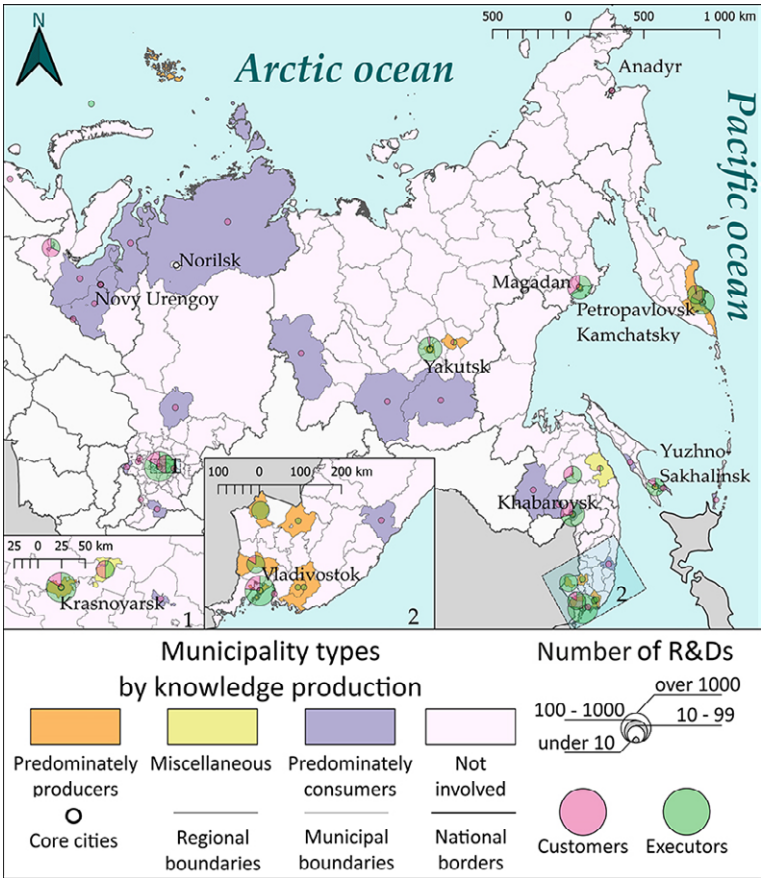

Figure 4. Typology of municipalities in the Pacific and Eastern Arctic basins for knowledge production

are predominantly consumers. Only 6% are assigned to the group of Predominantly producers: in the western part of the basin these are Arkhangelsk, Petrozavodsk, Apatity and Murmansk, and in the eastern part remote from the coast – Krasnoyarsk and Yakutsk. The Pacific basin also has a significant share of municipalities not involved in R&D – 79.2%. Among the other municipalities, the largest number are Predominantly producers – 11.9%, the group Predominantly consumers included 7.9%. Vladivostok, Khabarovsk, Petropavlovsk-Kamchatsky, and Magadan are most actively involved in the process of knowledge production.

Discussion and conclusions

The geography of innovation systems is configured based on the location and networking of the institutions involved in knowledge production and commercialization. Studies have proven that innovation activity requires a favorable milieu that enables entrepreneurship and fosters the generation of scientific and technological knowledge (Schot & Steinmueller, 2018). It is often stated that the institutional thickness of regional innovation systems is the key to generate, transfer, and absorb new knowledge – the cornerstone of the modern knowledge-driven economy (Rypestøl & Aarstad, 2018). Firms located in areas with rich and diverse territorial capital have higher chances for knowledge spillovers and cross-fertilization. In this context, coastal regions are of significant interest, as they have continuously been regarded as densely populated and well developed, enjoying the coastalization effects (Mikhaylov et al., 2018).

The widely described supremacy of coastal areas has been extensively studied with respect to demographics and industrial development but has received less attention in innovation studies (Witte et al., 2018). This is equally relevant for the research of Russian scholars: the maritime issues were a traditional research topic of Soviet human geographers, and in the recent years, it regained its prominence with a bias towards the assessment of the socio-economic development of territories (Druzhinin, 2022).

This article covers the gap by evaluating the spatial configuration of the knowledge production domain of the national innovation system, focusing on the role and embeddedness of the coastal regions located in different marine basins – the Baltic, Caspian, Azov-Black, Arctic, and Pacific. Being all located in a single country – Russia, there will be no difference in STI policy, providing a more insights on regional and municipal differentiations. It is noteworthy that the coastal municipalities of Russia cover 27.5% of the entire territory of the country and accumulate 14.2% of its demographic potential with an upward trend (as of 2019), while retaining pronounced parametric inter-municipal differences depending on the socio-economic development and length of the coastline (Druzhinin & Lialina, 2020).

In this research we have analysed the binary customer-contractor ties of 66,647 R&D projects across all regions and municipalities of the country with the aim of testing two hypotheses. *Firstly*, the urbanization factor was expected to cause asymmetry in the national innovation space, featuring active knowledge production activity in major cities and adjacent municipalities. It is found that the urbanization factor has the strongest influence – the largest centers of knowledge production are the largest cities of marine basins, giving impetus to the development of neighboring municipalities. Vivid examples are the Baltic Sea basin with the leadership of St. Petersburg as the largest national innovation center and the core city, and the Azov-Black Sea basin with a spatial triangle of core cities – Rostov-on-Don, Krasnodar, Simferopol-Sevastopol. Moreover, the stronger the core, the greater the effect of proximity to it on the knowledge production function. Although a significant part of the municipalities of coastal regions is still not involved in the knowledge production (above 70%), in marine basins with strong core cities the share of uninvolved municipalities is significantly lower.

Secondly, in line with the coastalization phenomenon, it is expected that innovation activity will be clustered in coastal areas and decline with the distance from the shoreline. Being tested at the municipal level, we did not observe a strong influence on the localization near the coast on the knowledge production (even negative correlation for the Arctic basin). However, the nature of funded R&D by coastal regions is specific, focusing on marine-related topics, this extends the findings by Pontikakis et al. (2009).

Our observations correspond with some recent studies held in the Baltic Sea region countries. For instance, Simensen and Abbasiharofteh (2022) have analyzed the R&D networks in Norway, showing the paramount role of large cities in the national knowledge production system (Oslo, Bergen, Trondheim, and Stavanger), although being less pronounced in the maritime-related sector. The municipal level research on public funding of research, development and innovation (RDI) across Finland held by Makkonen and Mitze (2022) suggests that major cities and the surrounding areas are represented by the most active firms, located in the coastal agglomerations of Helsinki, Turku, and Oulu. Notable that during the pandem-

ic year of 2020 the innovative activity of coastal and peri-urban municipalities increased.

Another phenomenon of spatial stratification of innovation activity in the coastal zone, which remained outside the scope of this study, is associated with its high international communication potential. Neighboring with the regions of foreign countries across the sea (Baklanov, 2022) supports the flow of knowledge and innovation, the 'stickiness' of which, among other things, is supported by a common maritime theme. Active trans-aquatic interaction is particularly typical for the countries of the Baltic Sea region, including the formation of specialized forms of maritime innovation activity (Meyer et al., 2021a,b). It can be assumed, as a future hypothesis, that coastal municipalities, which are also frontiers, are more actively involved in the generation of knowledge and innovation.

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