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CLUSTER ANALYSIS OF FACTORS EFFECTING THE DEVELOPMENT OF INNOVATIVE ACTIVITY AND INFRASTRUCTURE QUALITY

Abstract: *One of the priorities in terms of building an innovation economy and promoting innovation activities at all level is infrastructure development, i.e. a modality for integrating innovation processes at different levels and in different economic sectors. Among the most significant limitations to innovative growth is infrastructure qualitywhich conditions the investment appeal of national economy and the speed of return on investment. This paper adopted Ward's hierarchical clustering method to analyze various Russian regions. Cluster analysis revealed a direct correlation between infrastructure development indicators and innovation parameters. One of the disruptive factors is a time lag between innovation subjects' demand for individual infrastructure elements and their actual exploitation. In the current context, there is a need to develop projections and comprehensive plans for regional development, thereby improving the efficiency of innovation potential and eliminating the existing disproportions between the levels of innovative development.*

Keywords: *Cluster analysis; Innovation capacity; Innovative infrastructure; Information and communication infrastructure; Quality of infrastructure.*

1. Introduction

The innovative development of the Russian economy, defined as a priority area for economic reforms, is a focus of the regulatory control exerted by government structures. Innovations adopt a leading role in the socio-economic and technological development by enhancing the competiveness of innovation-based enterprises, creating new jobs and improving the population's quality of life and welfare. They also help reduce intraregional differences. Of special importance in this process is the level of infrastructure within the framework of regional innovation systems.

Innovative infrastructure – in its modern understanding – is multidimensional, systemic and not limited only to ensuring the innovative development process.

From the semantic point of view, the term 'infrastructure' is defined as the foundation, the internal frame of an entity or "a set of interrelated service structures that provide and/or ensure a basis for addressing a problem (a task)" (Big encyclopedic dictionary, 1998). The term is derived from two Latin words: infra ('under', 'below') and structura ('frame', 'location'). According to

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the Online Etymology Dictionary, the term has been used in the English language since the late 1920s, whereas the Oxford Dictionary states that this is a military term borrowed from the French language.

Various interpretations of infrastructure emerged in the first half of the 20th century in response to macroeconomic issues and crises. The term ‘infrastructure’ is said to have been introduced in economics in 1955 by Paul Rosenstein-Rodan (1961), the Austrian economist who elaborated an economic growth model for third world countries. Rosenstein-Rodan defined infrastructure as “a set of general environments to ensure the favorable development of private enterprises in the key economic sectors and to meet the needs of the entire population. In Rosenstein-Rodan’s view, its main elements were the following economic sectors: energy, transportation, agriculture, industry and communication whose development provides a material basis for the disposal of quickly repaying investment.

In the post-war years, economic growth became the most widely discussed topic in economics. Economists reached the conclusion that economic productivity and non-productivity growth is triggered by the so-called auxiliary industries (communication, transportation, power-producing companies and entities, the financial sector and the media) as well as certain social spheres (education, housing and public utilities, access to food and others).Infrastructure plays an auxiliary role in the field of innovation and has both a short- and long-term positive effect on economic performance as long as its quality is high. Importantly, the low quality of infrastructure is determined not only by technical/technological parameters, the extent of wear and progress rate, but also by low geographical connectivity, remoteness from economic centers and main transportation hubs throughout the country and in border areas.

Managing the development of economic infrastructure as an economic benefit is the prerogative of the State. Based on research results, InfraOne experts concluded that Russian infrastructure has been developed over several dozens of years with no coherent road map to territorial development and no unified statistical framework or condition assessment (Development index of Russian infrastructure). Infrastructure-building is a capital-intensive process requiring considerable budget funds to be spent on expensive and often unprofitable projects and programs. In this regard, federal and regional authorities are faced with, at least, two dilemmas over whether to invest in social or industrial infrastructure and whether to produce high-quality physical infrastructure entities or entities of lower qualities based on available funds. In elaborating long-term development strategies, however, government organizations should take into consideration the apparent direct relationship between infrastructure quality and quality of life reflected in transport systems, housing and utilities, urban upgrading, up-to-date school and hospital equipmentand so on.

Research confirms the existing relationship between the growth rate of innovative production and the population’s improved quality of life and welfare, especially in the industrially developed countries (Safronchuk, 2012). A number of specialists point out that advances in science and technology are a key factor behind the improving quality of products and services, labor and material cost savings, growth of productivity, the improving production organization and efficiency (Khasanova & Kapoguzov, 2009).

In our opinion, low production of innovative products, services and projects results ineconomic crises that go hand-in-hand with a decline in income and business competitiveness. If neglected, the emerging trends could lead, in the medium-to-long term, to a drop in innovation activities, human capital and the technological degradation of production sites.

In the context of the Russian economy's low innovative activity, high risks and uncertainty in the innovative sphere, public authorities are confronted with the problem of identifying the priority areas in terms of socio-economic development. Some researchers point to the need for optimal distribution of resources between innovation development through the innovative infrastructure of regions and production development through the development of innovative infrastructure (Kalenskaya, 2015).

The innovation-focused State policy should not only address the activities of companies, but also set up a macro-industrial infrastructure that any technological society needs to maintain its activities (Van De Ven, 1993). Importantly, investment in infrastructure can produce a multiplicative effect and give new impetus to overall economic growth. According to the specialists from InfraOneResearch, the minimum additional need in infrastructure investment in 2021 amounts for 3.4 trillion rubles and 7.2 trillion rubles are needed to boost the economy (Investment in infrastructure, 2019).

Russian regions differ significantly between themselves in terms of access to innovative resources because Russia's scientific and innovation capacity is concentrated in major research and industrial centers. Consequently, big business can be expected to show interest in the environments with the best possible investment conditions, which results in regional differentiation in the innovation sphere, further aggravated by the low investment appeal of economically depressed regions. As a result, the latter are isolated from external markets and (mainly financial) resources.

A shift to innovation economics requires the creation of an entirely new environment for spatial development that would ensure sustainable economic growth and lesser regional differentiation. Russian and foreign research has shown that innovative infrastructure established at the national and regional levels is the most important of such structures.

2. Methodology

The innovative national economic system is formed taking into account the regional economies' existing resource capacity, including the deployment of the existing innovative infrastructure, the availability of manufacturing facilities, intellectual resources and other competitive advantages in creating and launching advanced, knowledge-based products. Currently, the setup of regional innovation systems, including the deployment of existing infrastructure, is somewhat spontaneous, given that each region individually identifies its promising development areas and raises investment.

The scope of the present study is to assess how the quantitative parameters of economic infrastructure elements affect the innovation-focused activities of Russia's most advanced regions based on their clustering in terms of infrastructure indicators.

The study targets 14 federal subjects of Russia, selected on the basis of the maximum mean value of the share of innovative products, projects and services in the total amount of products shipped and projects/services carried out between 2014 and 2018 (Table 1).

What complicates the current state of the Russian economy's innovation sphere, characterized by weakly diversified production and insignificant high-tech exports, is a great number of of financial, economic and social issues that can only be addressed by implementing a number of comprehensive measures, and tangible results are most likely to be obtained in the long term. In this regard, there is a need to examine patterns relating to the spatial differentiation of regions, which will help categorize the Russian regions by innovation development taking into account the impacts of infrastructure factors. This task can be tackled by using a clustering method.

Table 1. Changes in the share of innovative production as a percentage of the total amount of products shipped and projects/services carried out between 2014 and 2018

No.	Region	2014	2015	2016	2017	2018	Average
1	Belgorod Oblast	4.4	5.0	7.3	11.6	14.9	8.6
2	Moscow Oblast	12.9	13.7	15.8	14.7	13.2	14.1
3	Moscow City	11.0	17.1	13.6	3.3	3.0	9.6
4	Yaroslavl Oblast	10.5	7.0	14.9	12.2	12.8	11.5
5	St. Petersburg	12.0	7.3	8.7	9.1	9.9	9.4
6	Republic of Mordovia	26.9	27.0	27.2	27.5	24.3	26.6
7	Republic of Tatarstan	20.5	20.4	19.6	19.6	20.9	20.2
8	Udmurt Republic	11.2	4.0	16.3	10.8	12.6	11.0
9	Chuvash Republic	12.1	12.2	13.1	12.2	11.2	12.2
10	Perm Krai	9.4	7.7	15.5	16.0	18.4	13.4
11	Nizhny Novgorod Oblast	21.3	15.8	16.5	15.4	15.7	16.9
12	Samara Oblast	21.1	19.1	17.7	15.6	13.5	17.4
13	Ulyanovsk Oblast	12.0	13.2	12.3	12.8	13.4	12.7
14	Khabarovsk Krai	12.5	10.8	14.1	23.8	21.3	16.5

Source: Federal State Statistic Office of the Russian Federation. URL: https://gks.ru/bgd/regl/b19_14p/Main.htm

A developed socio-economic environment contributes to innovation development at the initial and subsequent stages, but the question arises as to exactly which factors will foster the growth of innovative production. Therefore, the aim of the present study was to build an economic and statistical model that would assess the impact of infrastructure factors on the share of innovative products launched in Russian regions' economic space.

The present research is based on Ward's method that assesses the distance between entities through dispersion analysis directed at investigating the differences and dependencies of empirical data's mean values.

The need for clustering requires measuring three notions, i.e., connectedness, compactness and disconnectedness of cluster components. Connectedness is specified by the appropriate index of connection measured within the zero-to-infinity range. Compactness reflects the homogeneity of a cluster by examining the dispersion of intra-cluster data. Finally, disconnectedness considers distance between cluster centers. Compactness and disconnectedness are indicative of opposite trends given that compactness increases as disconnectedness decreases (Yadegari et al., 2018).

For the purposes of this study, Ward's method is used to obtain monotone clustering. This property makes is possible to build a dendrogram, i.e. a flat representation of the entire cluster structure with no self-intersections. This approach detects previously unknown yet practically useful information necessary to make recommendations as to applications of analytical outputs.

To analyze factors affecting innovation activity, this study uses three groups of statistical indicators describing the state of economic, information/communication and innovation infrastructure (Table 2).

Table 2. Groups of cluster analysis indicators

Groups of indicators	Statistical indicators
Economic Infrastructure	Fixed capital investment per caput at the then-effective prices (ruble, annual indicator value)
	Commissioning of residential and non-residential buildings, per caput
	Density of public hard-surface highways
	Density of railway lines at year-end, km of lines per 10,000 km2 of territory
Infrastructure of Information and Communication Technology (ICT)	Usage of ICT by organizations (local area networks), % of all organizations surveyed
	Usage of ICT by organizations (cloud services), % of all organizations surveyed
	Usage of specialized design software by organizations, % of all organizations surveyed
	Number of personal computers per 100 employees
Innovation infrastructure	Innovative activity of organizations
	Advanced production technologies in use, per 1,000 of industrial workers
	Share of machines and equipment (less than 5 years of service) in the total cost of machines and equipment used in research and development centers
	Growth of high productivity jobs

Source: prepared by authors.

Based on the selected factors, it is possible to put forward the hypothesis that the variables in Table 2 give a comprehensive description of economic infrastructure and can affect the share of innovative products in the total amount of products shipped.

The official data provided in the section Regional statistics: Socio-economic situation allow for a quantitative analysis and an assessment of the selected factors, followed by a classification of regions based on multivariate clustering that perceives its region wih a specific set of indicators as a point in a n-dimensional space – a 5-dimensional space, in our case. The clusters' centers of gravity are specified according to mean indicator values, and the distance between two clusters in measured in terms of an increase of the objects' Euclidean distance to centers. The Statistical Package for the Social Sciences (SPSS) was used to carry out cluster analysis.

3. Results

3.1. Economic infrastructure

Since infrastructure is closely related to economy, it is difficult to distinguish between the terms 'infrastructure' and 'economic infrastructure'. L.I. Lopatnikov's Economic and Mathematical Dictionary gives the following definition of the latter term: "Economic infrastructure is a combination of sectors and activities providing a common service to production and economy and creating a common foundation or frame for them. Economic infrastructure includes transport and communication facilities, warehousing, power and water supply, etc. Some researchers also count science, health care and the education system aspart of economic infrastructure, classifying them as the non-productive or social infrastructure of economy" (Lopatnikov, 2003).

Economic infrastructure has the largest and most diverse composition of all infrastructure groups and, as such, acts as a bond between all of the State's economic sectors and territorial segments.

From the perspective of the functional approach, economic infrastructure is an auxiliary part of economy that ensures the smooth operation of the entire economic system. The sectoral approach regards economic infrastructure as a combination of all economic sectors aimed at producing goods and services and providing the public good (Kuznetsova, 2010; Kheinman, 1982).

Some researchers (Moljevic, 2016) point to hard and soft infrastructure elements. Hard elements include State-managed standardization, accreditation and metrology whereas soft elements, such as the quality of services provided by organizations, the level of education and professional training, are administered at the regional level.

Economic infrastructure influences economic growth in several ways: as one of production factors, as a drive for production growth, as an incentive to boost demand for products and as a public policy tool. Notably, there is not only a direct relationship between the level of infrastructure development and economic growth (Khan et al., 2020; Rudra, 2019), but also an inverse relationship: a growing aggregate demand for products stresses, correspondingly, the need for infrastructure network development.

In this study, consideration was given to the specific values of the following indicators: fixed investment, commissioning of residential and non-residential buildings, density of public hard-surface highways and density of railway lines. This group of indicators is not directly related to innovative production, yet it determines, as J. Wang et al. (2020) point out, the economic potential of infrastructure which is one of the key elements of regional economic potential and a major factor behind sustainable territorial development.

Figure 1 shows a dendrogram for cluster analysis of regional economic infrastructure.

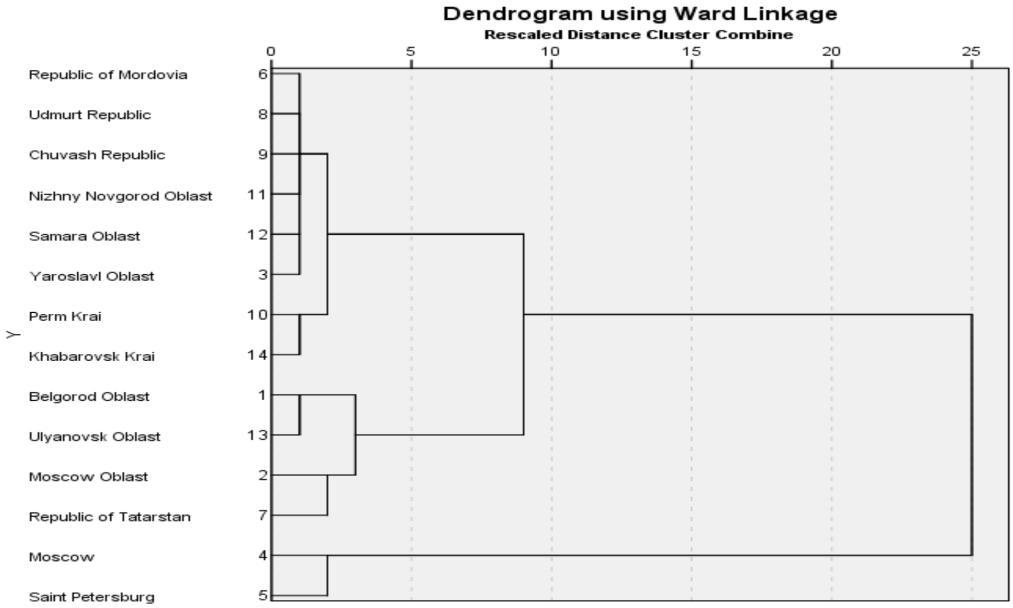

Figure 1. Dendrogram showing the clustering of Russian regions according to economic infrastructure indicators (2018)

Source: prepared by authors using Rosstat's data and SPSS Statistics. URL: http://www.gks.ru/bgd/regl/b1814p/Main.htm

The above figure reveals that the best option would be to identify three economic infrastructure clusters including the ***following federal subjects of Russia*****:**

Cluster 1: Belgorod and Ulyanovsk Oblasts;

Cluster 2: Moscow Oblast and Republic of Tatarstan;

Cluster 3: Republic of Mordovia, Udmurt Republic, Chuvash Republic, Nizhny Novgorod Oblast, Samara Oblast, Yaroslavl Oblast, Perm Krai and Khabarovsk Krai; and

Cluster 4: Moscow and St. Petersburg.

Table 3 specifies the quantitative parameters represented by mean values throughout the entire list of indicators available for each cluster.

Table 3. Inter-cluster differentiation of Russian regions' economic infrastructure indicators (2018)

Ward'sMethod		Fixed capital investment per caput at the then-effective prices (ruble, annual indicator value)	Commissioning of residential and non-residential buildings, per caput	Density of public hard-surface highways per 1,000 km2 of territory	Density of railway lines at year-end, km of lines per 10,000 km2 of territory
1	Average	76,810.50	1.39	490.34	222.82
	N_1*	2	2	2	2
2	Average	143,406.50	1.66	609.20	313.16
	N_2*	2			
3	Average n	75,939.38	0.80	251.00	167.79
	N_3*	8	8	8	8
4	Average	178,372.00	0.90	2,507.32	2,501.50
	N_4*	2	2	2	2
Total Average		100,335.21	1.02	658.69	529.81
N		14	14	14	14

*Ni – number of regions belonging to Cluster i
Source: prepared by authors using the Federal State Statistic Service of the Russian Federation and SPSS Statistics. URL: http://www.gks.ru/bgd/regl/b18_14p/Main.htm

All indicator values shown in Table 3, with the exception of the building commissioning indicator value, vary significantly: Cluster 4, which represents the metropolitan regions, tops the list. If the indicator values of Cluster 4 are taken as 100%, the results will be as followed.

In terms of fixed capital investment per caput at the then-effective prices, the value of Cluster 1 is 43.1% as compared to that of Cluster 4; consequently, the values of Clusters 2 and 3 are 80.4% and 42.6% respectively;

The indicator for density of public hard-surface highways shows greater discrepancies: Cluster 1 is 19.6% as compared to the leading cluster, Cluster 2 is 24.3% and Cluster 3 is only 10%;

The indicator for density of railway lines reveals the maximum relative deviation from the cluster having the best developed infrastructure: Cluster 3 has the lowest share (6.7%), followed by Cluster 1 (8.9%) and Cluster 2 with a share of 12.5% compared to the leader.

If specified as 'high', 'above/below average', 'average' and 'low', economic infrastructure development is as follows: Cluster 1 (average), Cluster 2 (above average), Cluster 3 (low) and Cluster 4 (high). The high, average and low economic infrastructure level can be interpreted as the coefficient of its quality development.

The specific value of fixed investment is the indicator that is most closely connected with innovation activities of territories because Russian investment policy is defined by investment’s focus on innovation when it comes to developing the productive base of economy. The sphere of major construction affects innovation development less directly, yet, on the other hand, additional commissioning of residential and non-residential buildings can be regarded as a favorable factor for innovators. Density of highways and railway lines has a positive impact on the logistic ICTand accelerated diffusion of innovations when dealing with innovative products that demand physical distribution in new areas of consumption.

3.2. Information and communication systems (ICTs)

According to experts, the ICTs are currently the only promising area of innovation development, which is in line with global technological trends resulting from a sharp increase in use of the Internet. International research shows a positive and statistically significant relationship between IT infrastructure and innovation performance, the latter having become development factors (Taka, 2010; Oladipo Olalekan, 2019; Jabbouri et al., 2016).

Figure 2 shows a dendrogram for Russia’s regional clustering in terms of information and communication technology indicators.

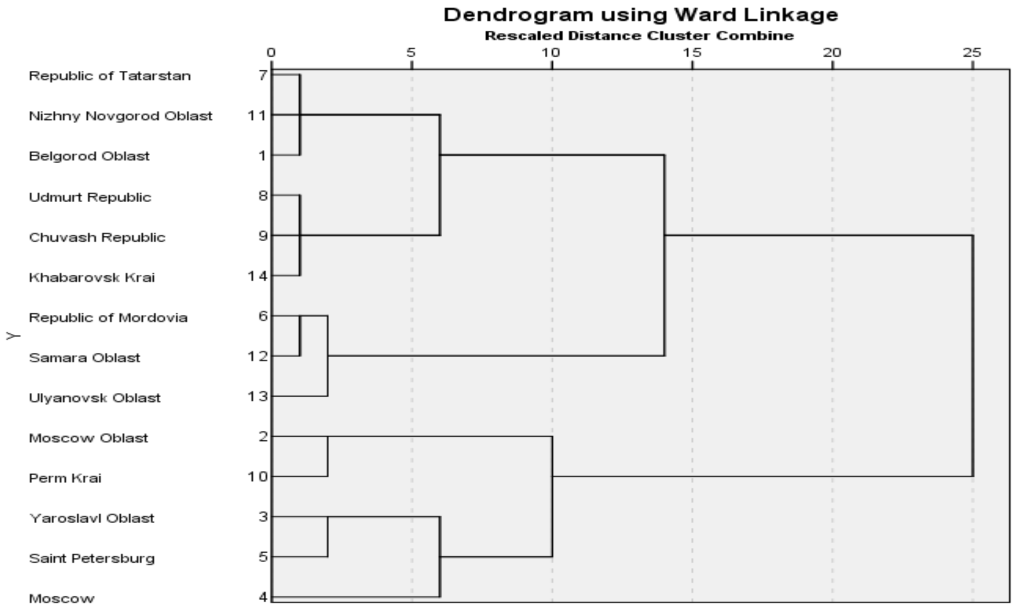

Figure 2. Dendrogram for Russia’s regional clustering in terms of information and communication technology indicators (2018)

Source: prepared by authors using Rosstat’s data and SPSS Statistics. URL: http://www.gks.ru/bgd/regl/b18_14p/Main.htm

The significance of information and communication technologies is increasing due to the adoption of the Government Program on Digital Economy of the Russian Federation in 2017 (Government Program No. 1632-r of 28 July 2017), aimed at setting out necessary and sufficient conditions of institutional and infrastructural nature. Without being limited to the development of information and communication technologies, the Program is, clearly, based on their application.

The following four clusters were selected according to indicators illustrating the development of information and communication infrastructure:

Cluster 1: Republic of Tatarstan, Nizhny Novgorod, Belgorod Oblast, Udmurt Republic, Chuvash Republic and Khabarovsk Krai;

Cluster 2: Moscow Oblast and Perm Krai;

Cluster 3: Yaroslavl Oblast, St. Petersburg and Moscow;

Cluster 4: Republic of Mordovia, Samara Oblast and Ulyanovsk Oblast.

Although the inter-cluster comparison of indicators for information and communication infrastructure also reveals regional differentiation, it highlights closer mean values: the range of variability is 11.6 p.p. for the first indicator, 19.8 p.p. for the second one, 9.9 and 19.7 p.p. for the third and fourth indicators respectively. All clusters show a relatively low level of information technology usage (Table 4).

Table 4. Inter-cluster differentiation of indicators for Russian regions' information and communication technology infrastructure (2018)

Ward'sMethod		Usage of ICT by organizations (local area networks), % of all organizations surveyed	Usage of ICT by organizations (cloud services), % of all organizations surveyed	Usage of specialized design software by organizations, % of all organizations surveyed	Number of personal computers per 100 employees
1	Average	68.200	27.650	13.000	49.33
	N_1	6	6	6	6
2	Average	66.500	32.700	21.250	45.00
	N_2	2	2	2	2
3	Average	71.200	32.167	18.067	64.67
	N_3	3	3	3	3
4	Average	59.633	19.833	11.567	48.00
	N_4	3	3	3	3
Total Average		66.764	27.664	14.957	51.71
N		14	14	14	14

*Ni – number of regions belonging to Cluster i
Source: prepared by authors using the Federal State Statistic Service of the Russian Federation and SPSS Statistics. URL: http://www.gks.ru/bgd/regl/b18_14p/Main.htm

In this case, clustering resulted in a different distribution of the investigated regions into groups compared to economic infrastructure clustering. The metropolitan regions are still in the top, by a slight margin, with the addition of a new member, Yaroslavl Oblast. Cluster 2 is now in the lead in terms of usage of cloud technologies and specialized software design programs. Interestingly, these parameters are closest to the indicator for production's innovation activities, characterized by the share of innovative products in the total amount of products shipped.

A previous study (Astapenko et al., 2019) established that an increase in organizations' usage of specialized design software by 1% led to a 0.97% increase in the share of innovative products in the total amount of products shipped. Consequently, a low usage of design software is undesirable and does not promote the innovative development of enterprises.

The level of equipment of information and communication infrastructure has great significance for the formation of digital economy and the intensification of innovation-focused production and of overall spatial development. However, the forward-looking provision of for-profit enterprises with computer equipment and specialized software will not produce the expected results as opposed to the intensity of innovators' creative work. Furthermore, the business community is unwilling to pay for resources not directly involved in the production process.

3.3. Innovation infrastructure

Innovation infrastructure is the integrating organizational form of innovation processes at macro and micro levels. Innovation activity comprises all scientific, technological, organizational, financial and commercial enterprises that produce innovations, in practice or conceptually. It is innovation infrastructure that can be seen as being of highest quality, given its focus on technological progress.The capacity for present and future innovation-focused development of territorial entities, including regions, is related to an available innovation infrastructure conducive to the development and diffusion of new technologies.

Being an economic category, innovation infrastructure was given different interpretations by researchers, hence ambiguity in their attitudes about indicators for assessing the state of innovation infrastructure. Initially, international researchers perceived innovation infrastructure as an element of national innovation systems (NIS); as a structure ensuring technological interactions between institutes and engineering firms (Lundvall, 1992); and as a medium for interactions within the institutional framework of the NIS (Freeman, 1987).

There is no single view on the main components or units of innovation infrastructure. According to some authors, an innovation infrastructure can be represented in the form of six functional units actively interacting between themselves during innovation activities, namely: investment/finance, information, marketing, production/technology, expert/consulting services and personnel (Larin & Gerasimova, 2014).

Alternatively, elements of innovation infrastructure can be examined through the lens of resources provided by organizations responsible for innovation infrastructure setup. These resources are as follows: technological support, information and consulting, financing, personnel training and marketing support (Raikhlina, 2012). Importantly, the dominant principle for setting up innovation infrastructure is the creation of a network model of innovation infrastructure development that includes industrial parks, research centers, technologies and business incubators (Kobzeva et al., 2012).

For analytical purposes, this study used official statistics that can also be attributed to innovation potential, based on the stages of the innovation cycle (Table 2). Figure 3 shows the results of the cluster analysis of Russian regions depending on the level of innovation infrastructure development.

The following four clusters were identified in terms of the innovation infrastructure indicator:

- *Cluster 1*: Belgorod Oblast, Republic of Tatarstan, Nizhny Novgorod and Ulyanovsk Oblast;
- *Cluster 2*: Moscow Oblast, Republic of Mordovia, Udmurt Republic and Perm Krai;
- *Cluster 3*: Samara Oblast, Khabarovsk Krai and Yaroslavl Oblast; and
- *Cluster 4*: Moscow, ChuvashRepublic and St. Petersburg.

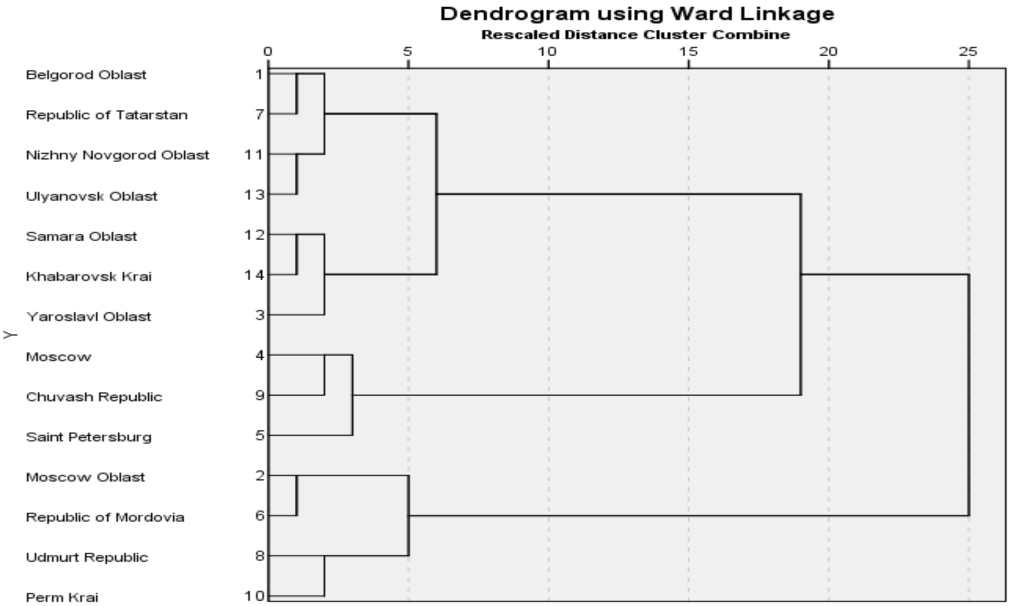

Figure 3. Dendrogram for Russia’s regional clustering in terms of information and communication technology indicators (2018)
Source: prepared by authors using Rosstat’s data and SPSS Statistics. URL: http://www.gks.ru/bgd/regl/b18_14p/Main.htm

Thus, the dendrogram in Figure 3 shows another way for Russian regions’ cluster distribution. Table 3 specifies the quantitative parameters represented by mean values throughout the entire list of indicators available for each cluster.

Table 5. Inter-cluster differentiation in terms of indicators for Russian regions’ innovation infrastructure (2018)

Ward’sMethod		Innovative activity of organizations	Advanced production technologies in use, per 1,000 of industrial workers	Share of machines and equipment (less than 5 years of service) in the total cost of machines and equipment used in research and development centers	Growth of high productivity jobs
1	Average	17.52	17.76	49.15	15.30
	N_1	4	4	4	4
2	Average	12.42	36.13	31.03	13.20
	N_2	3	3	3	3
3	Average	11.93	20.86	39.20	12.03
	N_3	4	4	4	4
4	Average	30.82	21.19	39.73	21.90
	N_4	3	3	3	3
Total Average		17.71	24.41	39.82	15.41
N		14	14	14	14

*Ni – number of regions belonging to Cluster i
Source: prepared by authors using the Federal State Statistic Service of the Russian Federation and SPSS Statistics. URL: http://www.gks.ru/bgd/regl/b18_14p/Main.htm

As far as inter-cluster differentiation is concerned, there are apparent contradictions in the the quantitative description of innovation infrastructure. First, no cluster has any clear leader in any of the indicators. Second, each cluster shows a maximum mean value for, at least, one indicator, and the first three clusters have at least one minimum. In addition to the above-mentioned specificities, others are as follows:

- The best situation with respect to equipment updates in research organizations, which is typical of Cluster 1, contradicts the minimum level of advanced production technology usage in other clusters;
- In Cluster 2, the situation is exactly the opposite: despite the maximum usage of advanced technologies, it has a minimum level of production facility updates;
- Cluster 3 can, on all grounds, be grouped among outsiders, given that two indicators out of four have minimum values and the other two are below average;
- In Cluster 4, a high level of innovation activity among organizations is consistent with the highest growth in high productivity jobs.

It is noteworthy to mention that the mean values of most parameters vary considerably in this group. A high percentage of organizations, usage of advanced production technologies and growth in high productivity jobs have been found not to guarantee achievement of the appropriate level of innovative production.

4. Discussion

The results of the study lead to the conclusion that the infrastructure factors are in themselves a necessary yet insufficient condition for innovation growth, despite the high-quality characteristics of specific groups of infrastructure entities. Today, new challenges are being posed to the quality of innovation infrastructure. Geographical connectedness implemented through the development of infrastructure networks is necessary in addition to infrastructure progressiveness, that is, conformity to advanced technology trends.

As of now, economic infrastructure does not have any manifest influence on the extent of innovative production. Thus, Moscow and St. Petersburg, the inter-cluster differentiation leaders in the first group of indicators, have a lower relative level of innovative production among the most technologically advanced regions. On the contrary, the innovation leader (Republic of Mordovia) has the worst economic infrastructure indicator values.

The degree of development of the ICTs directly affects the ability to remotely manage production processes, the development of unmanned vehicles and other digital economy technologies. The level of ICTs also affects the number of organizations using ICTs for economic purposes in local area networks and cloud services. This dependence, however, is neither absolute nor invariable.

The summary table (Table 6) shows the final stage of cluster analysis in which comparison can be made between the levels reached by each region in the three groups of factors within the corresponding clusters. The results showed an imbalance between factor indicators and, in some cases, the absence of influence of economic infrastructure on innovation activity.

Yaroslavl Oblast, the Republic of Mordovia, the Udmurt Republic, Perm Krai, Samara Oblast and Khabarovsk Krai show the worst results as regards development prospects. In some regions – the Chuvash Republic and Nizhny Novgorod Oblast – the level of innovation infrastructure is higher than that of economic infrastructure.

Table 6. Table summarizing cluster analysis results

Region	Economic infrastructure	Information and communication infrastructure	Innovation infrastructure
BelgorodRegion	average	average	average
MoscowRegion	above average	above average	below average
YaroslavlRegion	low	high	low
Moscow	high	high	high
St. Petersburg	high	high	high
RepublicofMordovia	low	low	below average
RepublicofTatarstan	above average	average	average
UdmurtRepublic	low	average	below average
ChuvashRepublic	low	average	high
PermKrai	low	above average	below average
NizhnyNovgorodRegion	low	average	average
SamaraRegion	low	low	low
UlyanovskRegion	average	low	average
KhabarovskKrai	low	average	low

Source: prepared by authors

The results of Russian regional clustering according to innovation infrastructure indicators reveal the need to develop national and regional innovation systems that would ensure communication between innovation centers, public authorities, the business community and other participants in the innovation process.

5. Conclusion

The analysis revealed the strengths and weaknesses of Russian regions. Despite a weak economic infrastructure, ICTs and innovation infrastructure are being developed in a number of regions such as the Chuvash Republic, Nizhny Novgorod Oblast, Perm Krai and the Udmurt Republic. The advanced infrastructure development of Moscow and St. Petersburg and its impact on innovation largely depends on the latter’s role in the innovation process. All other regions, excepting Samara and Belgorod Oblasts, show an unbalanced level of infrastructure development (Ulyanovsk Oblast, Yaroslavl Oblast, etc.)

One of the tools for linking the economic space are research and industrial clusters, since they establish direct economic contacts among federal subjects by redistributing innovation resources, income and expenditure that develop innovative production in regions on the basis of the objective market laws. To improve innovation activity, the territorial administration has to encourage conditions for promoting human capital and the creative potential of innovators and offering effective incentives to implement, produce and diffuse innovations.

As a result, it is necessary to introduce a policy aimed at improving the infrastructure potential of territories as innovative and economic production develops in regions. Carrying out innovation-related tasks before the creation of necessary socio-economic conditions, including infrastructure ones, could lead to waste of economic resources. Consequently, in developing innovation activity, Russian regions should not only finance infrastructure projects but also focus on the following.

First, create conditions to increase interest of highly qualified personnel in producing new knowledge, innovation technologies and innovation business;

Second, provide incentives to introduce new knowledge, technologies and technical approaches on an ongoing basis by encouraging interest in new markets and shaping consumer preferences among various sectors of the population;

Third, provide a basis for expanding innovation activity by merging and using interregional interaction resources of regional authorities, the academic and business communities.

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