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Higher Education and Innovation Potential in Russian Regions: Territorial Distribution*

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ABSTRACT

This paper investigates the territorial distribution of innovation potential across Russia, taking into account the role of higher education in the knowledge economy. The purpose of the research reported here was to determine the key characteristics of the territorial distribution of innovation potential across Russia and explore its relationship with the development of higher education in the country's regions. The paper presents a hypothesis about the uneven distribution of innovation potential across Russia and its concentration in particular regions with a well-developed system of higher education. The study's methodology is focused on identifying a region's scientific-technological, workforce, investment, and production potential in the structure of its innovation potential. The hypothesis was tested using the RStudio computing environment via correlation-regression and cluster analyses of the regions' innovation potential. The authors employed a set of methods related to probability-based and hierarchical approaches (k-means clustering, complete-linkage clustering, Ward's method, and DIANA) and drew upon a body of official statistical data on socio-economic development in Russia's 85 constituent regions, taking into account the effect of the higher education system on their innovation potential. The following result was achieved – supporting the hypothesis about the uneven territorial distribution of innovation potential across Russia and the role of institutions of higher learning in that.

Based on the insights gained from the study, the authors drew the following conclusion. Innovation potential in Russia is currently characterized by a high degree of concentration in particular regions. Most Russian regions have moderate to low innovation potential. Regions with high innovation potential are positioned in a compact arrangement (which helped identify the country's key areas in terms of innovation potential concentration). The contribution of universities in terms of turning out innovative products is

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relatively minor, with a significant portion of their research revenue resulting from government funding and grant-based activity and with businesses taking a minimal part in the development of R&D proposals. This is testimony to the low degree of integration of the system of higher education into the process of creation of innovative products and the lack of a developed mechanism for the interaction of universities and businesses in the country at the moment.

1. INTRODUCTION

At present, Russia is characterized by uneven regional socio-economic development, which is a contributing factor in income inequality in the country. Accordingly, some regions provide a significantly better standard of living and quality of life for the majority of their population than others do. Growing gaps in socio-economic development in the country's regions are conducive to growing social tensions and strengthening centrifugal forces in the country. In this regard, society and the state must be interested in reducing the distance between the leading and trailing regions. There is a need to preserve the potential for economic growth in the leading regions and create additional opportunities for socio-economic development in the trailing ones.

A region's socio-economic development is governed by a number of factors. One of the most significant of them is implementation of innovation and new technology (Du et al., 2020). A region's capacity and potential to conduct innovation-focused activity is what defines its innovation potential. The development of a region's innovation potential helps lay the groundwork for steady long-term economic growth. Taking this into account, a region's innovation potential may be construed as a systemic characterization of its economy that reflects the latter's ability to generate, implement, and adopt new solutions, both technological and organizational-managerial (Wang et al., 2019).

A region's innovation potential is linked with the level of development of its higher education system. Regions where universities have a well-developed material base are distinguished by high levels of research and innovation activity, tending to be poles of attraction for youth. With that said, the degree of influence of the higher education sector in terms of a region's innovation potential and innovation-based development may vary significantly from region to region. As indicated by Etzkowitz's triple helix model, universities play a more pronounced role in the knowledge economy. Thus, in selecting tools to help overcome high levels of uneven socio-economic development across regions, it makes sense to take account of the characteristics of how their innovation potential is formed and realized. Providing an integrated, scientifically substantiated solution to this problem may require investigating the regional distribution of innovation potential across Russia factoring in the input of the higher education system into its development (Lazányi et al., 2017).

Regions' innovation potential has been explored in numerous studies. The theoretical foundation for research on regions' innovation potential was largely laid by the research from L. Suarez-Villa (Suarez-Villa, 1993) and M. Feldman (Feldman, 1994). In Russia, applied research on regions' innovation potential has been conducted by the National Research University Higher School of Economics (Abdrakhmanova et al., 2020) and the Association of Innovative Regions of Russia (Rating of innovative regions of Russia, 2020). There is also a study of the innovation potential of Russian regions by V. Baburin and S. Zemtsov (2017). A significant portion of research on regions' innovation potential has been conducted in the context of exploring their innovation-based development and innovation activity. The world's most prestigious rankings on regions' innovation-based development take into account a variety of indicators that characterize their innovation potential. For instance, there is the Russian Regional Innovation Development Ranking, developed by the National Research University Higher School of Economics (Abdrakhmanova etr al., 2020). This system is based on computing a composite index that takes account of the socio-economic conditions governing a region's innovation-focused activity and scientific-and-technical potential.

In the Western literature, regions' innovation potential is often viewed in the context of their innovation activity. A good example is the study by T. Brenner and T. Broekel (Brenner and Broekel, 2011). Regions' innovation potential is partly taken into account in the European Regional Innovation Scoreboard

(RIS) (European Commission. Regional Innovation Scoreboard, 2019). Indicators characterizing innovation potential are also taken into account in constructing international rankings on innovation-based development, like the Global Innovation Index (Cornell University, INSEAD, and WIPO, 2020) and the European Innovation Scoreboard (European Commission. European Innovation Scoreboard, 2020).

A review of the latest research on the subject indicates that the majority of researchers prefer to investigate regions' innovation potential using an index-based approach. The use of this approach involves calculating a special summarizing indicator – the composite index – based on a particular set of indicators. Research on regions' innovation potential conducted using an index-based approach is distinguished by significant variability, with methodologies differing in terms of selection of initial indicators, indicator normalization and integrated index calculation methods, weighting coefficients for interim indices and initial indicators, etc. However, innovation has also been studied in the higher education context (Grabaraet al., 2020).

Using an index-based approach to exploring regions' innovation potential has several advantages to it. Specifically, the use of a summarizing indicator helps perform easily the ranking of regions on the basis of the state of development of their innovation potential. This explains the wide use of an index-based approach in creating rankings of regions' innovation-based development. At the same time, using an index-based approach to explore regions' innovation potential comes with a number of downsides. The main weakness is the low prognostic potential of the composite index. Calculating the composite index does not make it possible to assess the prospects for a region's innovation-based development. Secondly, the results from research into a region's innovation potential based on the use of an index-based approach is distinguished by high sensitivity to the set of indicators being integrated, the integration method, and the weights of various indicators and interim indices. Even slight changes to the initial system of indicators or the weighting coefficients assigned to them may alter the study's results significantly.

Based on the above, it may be concluded that, despite the large number of publications devoted to the study of the innovation potential of Russian regions, the subject will need further investigation. This is associated with the fact that the bulk of contemporary research on the regional distribution of innovation potential is grounded in the use of an index-based approach. This approach has a number of significant drawbacks and will need fine-tuning.

2. METHODOLOGY

A region's innovation potential, i.e. its economy's ability to generate, implement, and adopt new solutions, is governed by a number of factors. Firstly, there is the need for a workforce that will be capable of developing and implementing innovative solutions and turning out high-tech products. Secondly, there is the need for a relevant production base. Thirdly, creating and implementing innovations in a region requires significant investment. Fourthly, there must be relevant demand for innovations and innovative products turned out in a region. There are many other factors as well. The degree of influence on innovation potential varies significantly from factor to factor, too. It is worth focusing on the following key components of a region's innovation potential: a) the region's scientific-technological potential; b) the region's workforce potential; the region's investment potential; the region's production potential.

There are a number of common systemic characteristics known to influence certain key components of innovation potential. Firstly, it is the attractiveness of life in a region. Healthcare, culture, and social infrastructure are important determinants influencing one's choice of where to live and, accordingly, governing internal migration. The standard of living largely determines consumer demand for innovative products. Secondly, it is the vocational training system. The quality of vocational training determines the workforce potential of the science and business sectors. Regions' innovation potential can be measured using a system of indicators characterizing the key components of innovation potential. The fact that Russian regions differ from each other significantly in terms of population size, the economy, geography, and other parameters will require the use of relative indicators.

The selection of indicators for use in the study was performed in the following way. To begin with, based on a statistics methodology commonly accepted in the Russian Federation, the authors calculated

a set of indicators reflecting the effect of various factors on a region's innovation potential and determining its state. The authors analyzed the values of 50 relative indicators. The study's information base was official statistical data on a region's socio-economic development (Regions of Russia. Socio-economic indicators, 2019) and data from reports produced using the 2-Science (Information on the implementation of research and development, 2019) and VPO-2 (Information about the material and technical and information base, financial and economic activities of the educational organization of higher education, 2019) forms for 2018. The study was conducted using the RStudio computing environment.

The indicators were filtered based on the findings from a correlation-regression analysis. The criterion for selection was that there is a significant relationship between the indicator and the outcomes of innovation-focused activity. The authors used 'Relative Share of Innovative Output in the Total Volume of Goods Shipped, Works Performed, and Services Rendered' as the resulting indicator. The relationships were assessed by way of Spearman's rank correlation (R_{XY}). Next, the regions were grouped based on the level of development of innovation potential in them. The grouping procedure was performed based on the findings from a cluster analysis encompassing a set of indicators characterizing a region's innovation potential. Prior to that, the indicators' values were normalized relative to the average value. The clustering procedure was performed using probability-based and hierarchical approaches. The following methods were employed: k-means clustering (Hartigan and Wong's algorithm (Hartigan, J.A., Wong, M.A., 1979), complete-linkage clustering, Ward's method, and DIANA. Euclidean distance was used to calculate distance. The set number of iterations for the k-means algorithm was 25. The average silhouette method was used to determine the optimal number of clusters. The cluster identification procedure was performed by way of calculating and juxtaposing the average values of the indicators for each cluster.

3. RESULTS

The filtering procedure helped discard a significant portion of the indicators. The largest correlation ($|R_{XY}| > 0.4$) with the resulting indicator was exhibited by the indicators listed in the following table:

Table 1. Correlation between the Indicators Characterizing a Region's Innovation Potential and the Resulting Indicator

Indicator	R_{XY}
Spending on innovation-focused activity in organizations, % of Gross Regional Product	0.55929373
Level of innovation activity in organizations, %	0.52833082
Proceeds from R&D in institutions of higher learning, % of Gross Regional Product	0.50535898
Internal spending on R&D, % of Gross Regional Product	0.48405717
Relative share of machinery and equipment used in R&D in the total value of fixed assets, %	0.48218221
Output of bachelor's, specialist's, and master's degree graduates per 1,000 of employable age	0.48116881
Capital expenditure on R&D, % of Gross Regional Product	0.48046020
Admission into bachelor's, specialist's, and master's degree programs per 1,000 of employable age	0.47368967
Relative share of machinery and equipment aged up to five years used in R&D in the total value of fixed assets	0.46146723
Relative share of intangible fixed assets in institutions of higher learning (including their branches) in the total value of fixed assets	0.43301681
Relative share of personnel engaged in R&D in the total number of employed residents	0.4108206
Relative share of fixed assets used in R&D in the total value of fixed assets	0.40142318
Number of postgraduates per 1,000 residents of employable age	0.40107304
Budgetary subsidies to fund the execution of government contracts in the area of research activity per one employee engaged in R&D	-0.4875432

Source: own

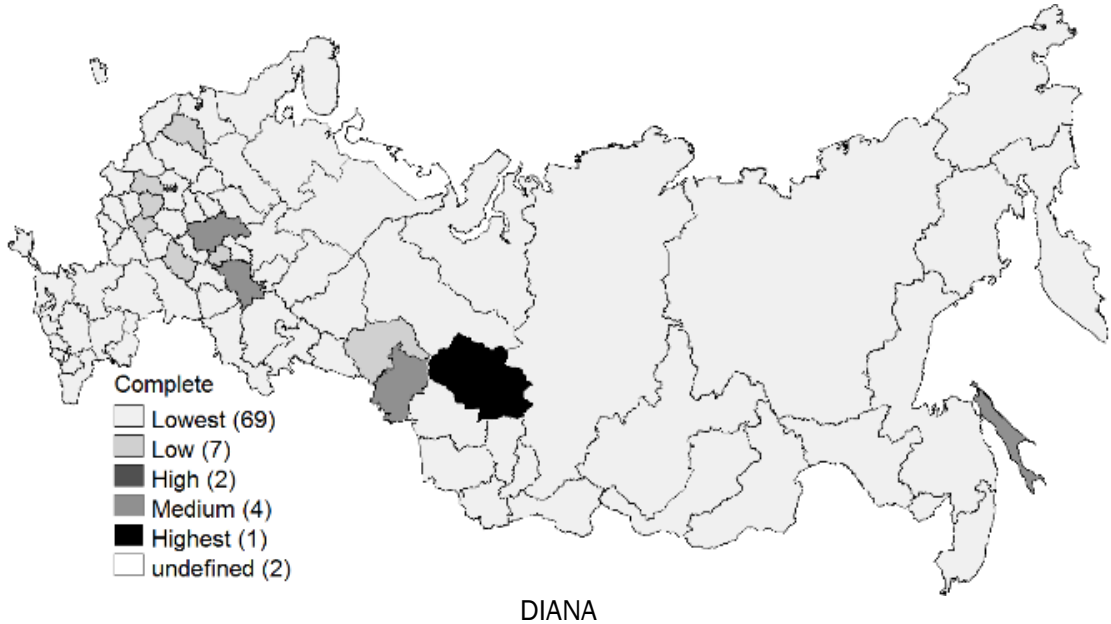
It is not advisable to make use of all indicators characterized by a tangible correlation with the resulting indicator, as there is a relationship between them. For use in further cluster analysis, the authors selected the indicators with the strongest correlation with the resulting indicator ($|R_{XY}| > 0.5$):

– level of innovation activity in organizations (C1);
– spending on innovation-focused activity in organizations, % of Gross Regional Product (C2);
– proceeds from R&D in institutions of higher learning, % of Gross Regional Product (C3).

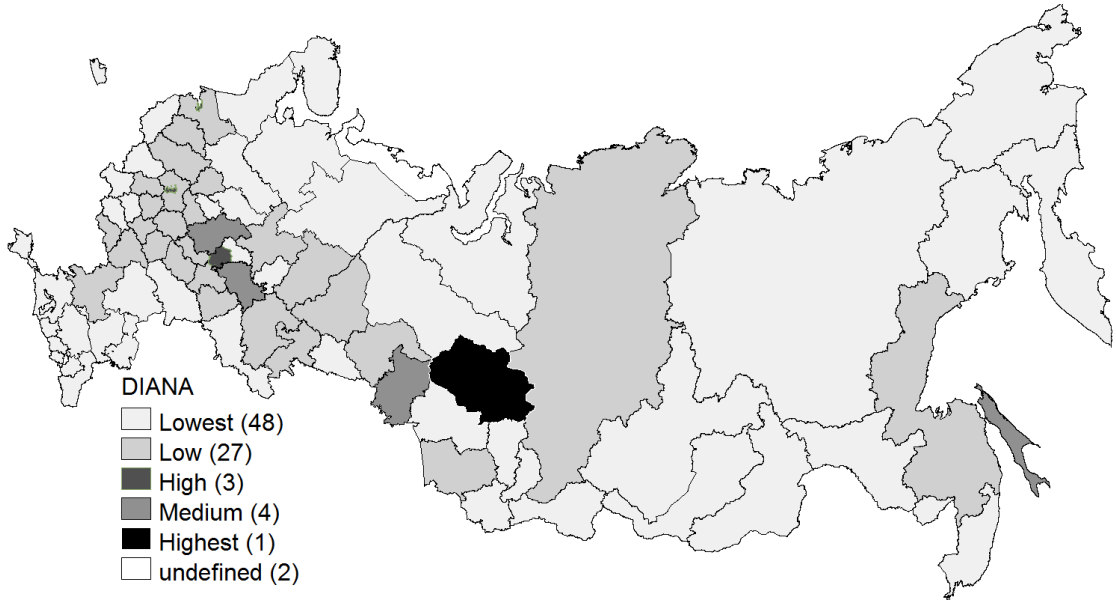
Calculating the pairwise coefficients of rank correlation between the indicators revealed the absence of a significant relationship between them.

Based on the findings from the cluster analysis, the regions were distributed into five groups – regions with very high, high, medium, low, and very low innovation potential. The distribution of the regions across the clusters, obtained using various methods, is illustrated in Figure 1.

Complete-linkage clustering



DIANA



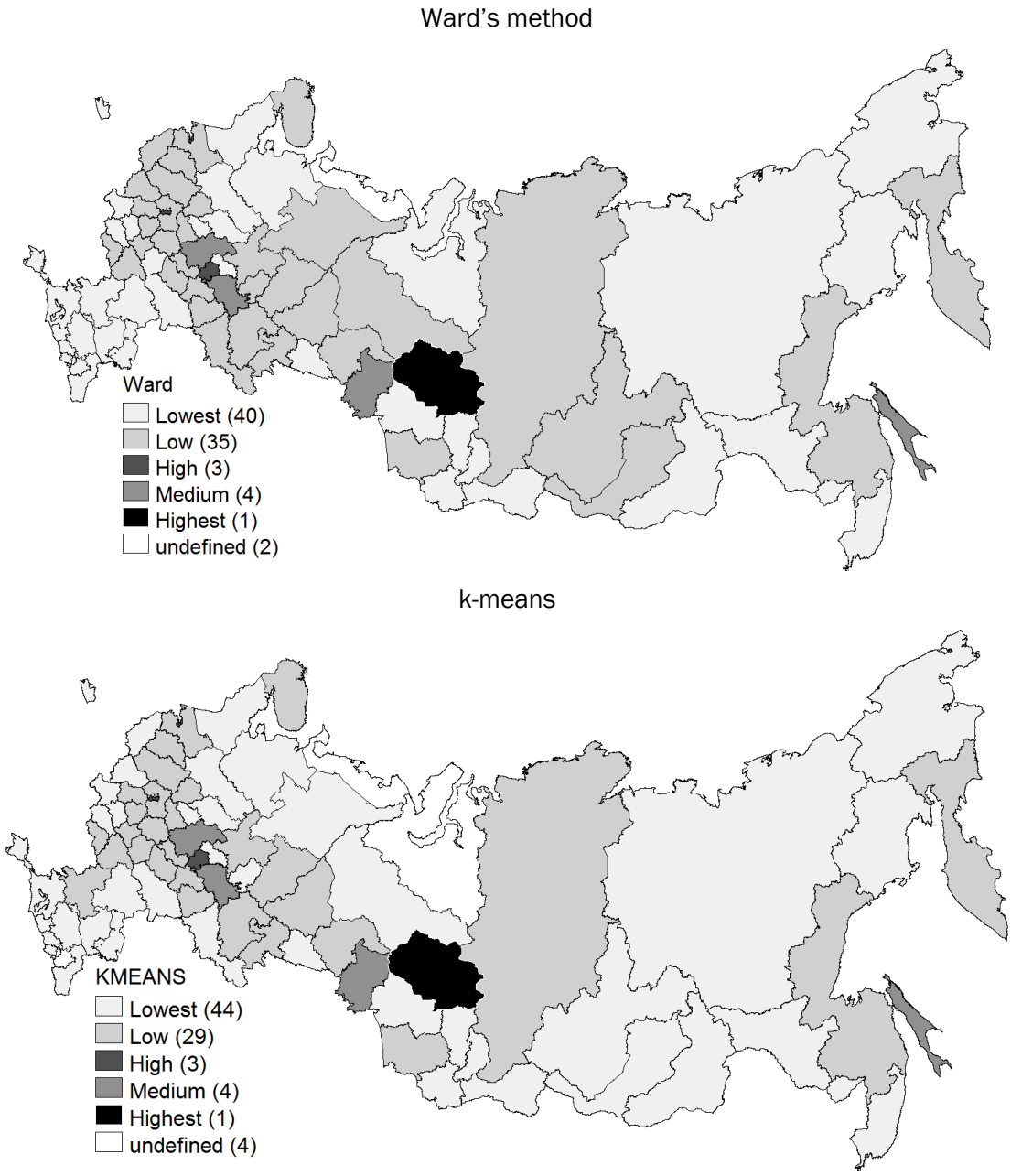


Figure 1. Level of development of innovation potential across Russian regions.

The clustering procedure helped identify a Russian region with very high level of innovation potential – Tomsk Oblast. The regions with high innovation potential included Moscow, Saint Petersburg, and the Chuvash Republic. Note that when the clustering procedure was performed using the complete-linkage clustering method the Chuvash Republic ended up in the group of regions with low innovation potential. Sakhalin Oblast, Omsk Oblast, the Republic of Tatarstan, and Nizhny Novgorod Oblast were rated as regions with medium innovation potential. The rest of the regions were rated as having low to very low innovation potential.

Note that using different clustering methods in the study produced a number of similar, comparable results. Specifically, similar results were obtained on regions with very high, high (except for the Chuvash Republic), and medium innovation potential. There were variances between the results from the division of regions with low and very low innovation potential. Thus, it may be concluded that the results were sustainable.

4. DISCUSSION

The results helped draw several conclusions about the nature of territorial distribution of innovation potential in Russia and gain an insight into its key characteristics.

The findings from the correlation analysis revealed an inverse relationship between the relative share of innovative output in total output and the size of budgetary subsidies to fund research activity. This confirms the fact that the active subsidizing of R&D as part of government contracts in Russian regions directed at the development of fundamental science does not ensure a significant increase in the share of innovative output in the total volume of production. With that said, the study found no significant relationship between the funding of R&D in the form of grants from state non-budgetary funds and in the form of direct budgetary subsidies for research. This may be testimony to that economic return from subsidized R&D is not the state's highest-priority criterion for the direct funding of science. Given the entrepreneurial sector's low interest in the development of fundamental science, the government gets to subsidize R&D just to keep the sector going.

The study detected a tangible relationship between the relative share of innovative output in total output and the share of university revenue from R&D in Gross Regional Product. Specifically, regions where universities are more actively engaged in R&D commercialization are exhibiting significant results on innovation-focused activity (Tvaronavicienė et al., 2018; Imbrișcă and Toma, 2020). This is also substantiated by the existence of a moderate direct link between the relative outcome of innovation-focused activity in a region and the relative share of colleges' intangible assets in the total value of fixed assets. With that said, the share of university revenue from R&D in total innovative output is 2.4%. Thus, the higher education sector's ultimate contribution remains minor. Besides, 44.9% of university revenue from R&D comes from budgetary outlays and state non-budgetary funds. This may be testimony to institutions of higher learning in Russia interacting poorly with the business sector at the moment.

The findings confirmed the high level of differentiation among Russian regions in terms of the level of development of their innovation potential. At present, the country has few regions with high innovation potential. The majority of Russian regions have low to very low levels of development of innovation potential. The territorial distribution of innovation potential in the country is distinguished by high levels of concentration. Regions with high, very high, and medium innovation potential are positioned in a compact arrangement, with many sharing a common border. These regions are characterized by a concentration of colleges with an engineering-technical focus, whose R&D outcomes tend to form the basis for technological modernization of production, both within the actual regions and outside of them.

The study produced a number of particularly interesting findings. Firstly, it helped identify the country's leader region in terms of innovation potential – Tomsk Oblast. The region's high innovation potential must be associated with the innovation and research activity of the universities operating within it. In Tomsk Oblast, the share of university revenue from R&D in Gross Regional Product is currently much higher than in other regions of the country. With that said, the relative outcome of innovation-focused activity in Tomsk Oblast is not high. This may be testimony to innovation potential not being utilized to the fullest in Tomsk Oblast at the moment. In this regard, it may be worth conducting further research in the area of exploring the factors governing the high activity of universities in Tomsk Oblast in R&D commercialization.

Secondly, of interest are the equivocal results from the determination of the level of development of innovation potential in the Chuvash Republic. Based on official statistical data, this region is distinguished by high levels of innovation activity in organizations operating within it. With that said, the region has posted moderate relative results in terms of innovation-focused activity. Even worse, the Chuvash Republic appears to be among the worst performers in share of university revenue from R&D in Gross Regional Product. Thus, it seems advisable to conduct further study of factors governing the high levels of innovation activity in the Chuvash Republic.

CONCLUSION

The overwhelming majority of Russian regions are characterized by low to moderate innovation potential. Regions with high innovation potential are relatively few in the country, and they are positioned in a compact arrangement. This is testimony to the fact that in Russia innovation potential is distributed quite unevenly and concentrated in particular areas.

The state regulates innovation-focused activity in regions using various mechanisms for subsidizing research and development. With that said, there is no direct significant relationship between the relative size of this funding and the relative share of innovative output in total output.

There is a tangible relationship between universities' innovation and research activity and the relative outcome of innovation-focused activity in Russian regions. Nevertheless, regional universities are poorly integrated into the innovation chains. This is reflected in the minor share of university revenue from R&D in total innovation output. A significant portion of this revenue results from government funding.

Thus, the study's proposed hypothesis was supported. The findings point the way toward further in-depth study of factors (including those related to spatial interaction) for the development and use of regions' innovation potential in the context of the triple helix model taking account of the role of the education sector in the value chain.

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