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Typology of Innovative Development of AIRR-Regions (Association of Russian Innovative Regions)

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Abstract

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The article describes typology of regions of AIRR based on factor and cluster analysis. The main purpose of typology in this study is seeking for opportunities to transform interregional differentiation from problem into an additional source of development of regions with different complementary models of innovation development. It highlights 4 main and 2 additional types (subtypes) of regions of AIRR: Type 1 “Industrial innovation-active regions” (Subtype 1 “regions with developed medium-technological industries” and Subtype 2 “regions with developed high-technological industries”), Type 2 “Industrial regions providing demand for innovations (“market”), Type 3 “Regions with developed scientific-educational complex”, Type 4 “Mixed (catching-up)”. Peculiarities of different types of regions allow each region achieving an efficient innovative activity through complementarity of resources if each region fulfills its role, defined by type of innovative development. It makes actual the problem of development of mechanism of interregional innovation policy as one of the area of development of a synergistic approach in the state innovative policy.

Keywords: Typology of regions, AIRR, factor analysis, cluster analysis, ANOVA.

1. Introduction

Over the past two decades in the advanced economies it’s observed substitution of the closed model of innovation process by the open one (i.e. the model of open innovations), which is based on a synergetic approach (Burets, 2014). The state innovative policy based on the open model should not operate tools on alignment of the regions in terms of innovative development but should utilize the regional variety as an opportunity for innovative development (Akerman at al., 2010, 2015). In addition, the systems having heterogeneous components (dominant, supplementary, auxiliary and etc.) are adjusting better to the changing environment and have a greater sustainability.

In this regard, it's significant for Russia to study innovative systems through the special frames concerning possibilities of interregional cooperation when forming an integrated innovative space from the subjects (regions) which are remote from each other.

Presently AIRR is the only precedent of self-organization of the regions in Russia (in industrial innovative aspect), that's why this association was selected as an object of this study. Membership of regions in AIRR is a political position, expressing willingness to collaboration in the field of innovative activity and laying the foundation for innovative cooperation that defines interest of the state authorities of these regions in working out different mechanisms of such cooperation. Currently 14 regions are members of AIRR: Republic of Bashkortostan, Tatarstan, Mordovia Republic, the Altai Territory, the Krasnoyarsk Territory, the Perm Territory, the Irkutsk Region, the Kaluga Region, the Lipetsk region, Novosibirsk region, Samara region, Tomsk region, Tyumen region and the Ulyanovsk region.

The main purpose of the typology in this study is seeking for opportunities to transform interregional differentiation from problem into an additional source of development of regions with different complementary models of innovation development.

2. Materials and Methods of Study

18 indicators, given in table 1, were used for building a model of innovative development of regions of AIRR. The indicators covers the different aspects of the regional innovative processes: structure and size of innovation-driven economy, expenditures of financial and labour resources for R&D and innovations, development of scientific and educational complex, area of intellectual property, results of innovative activity.

Table 1. Grouping of indicators of innovative development of regions of AIRR.

Group of indicators	Indicators of innovative development of regions of AIRR
1. Major indicators of development of innovation-driven economy	1.1 Gross Regional Product (GRP) per head, RUR 1.2 Share of products of high-technology and knowledge-intensive industries in GRP, % 1.3 Innovative activity of organizations, % 1.4 Ratio of small enterprises implementing technological innovations among small enterprises, %
2. Expenditures on R&D, innovations	2.1 Share of internal expenditures on research and development in GRP, % 2.2 Expenditures rate on technological innovations, % 2.3 Internal operational expenditures on foundational research by one organization performing research activity, mln. RUR. 2.4 Internal operational expenditures on applied research per one organization performing research activity, mln. RUR.
3. Scientific and educational complex, intellectual property	3.1 Share of staff engaged for research & development projects, in economically active population, % 3.2 Total score of regional universities entered the top 100 of the universities in Russia (according to "National rating of the universities") 3.3 Coefficient of inventive activity 3.4 Use of results of intellectual activity, units. 3.5 Use of results of intellectual activity by one innovation-active organization, units.
4. Results of innovative activity	4.1 Ratio of innovative products, work, services in total volume of shipped products, performed work, services, % 4.2 Developed advanced production technologies, units. 4.3 Quantity of the developed advanced production technologies per one organization

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	implementing research activity, units.
	4.4 Quantity of advanced production technologies used, units.
	4.5 Quantity of advanced production technologies used by one innovation-active organization, units.

The initial database was compiled on the basis of average values of indicators for each region for the period of 2010-2014 and was standardized. Multidimensional statistical methods were used in the present study: correlation, factor, analysis of variance (ANOVA) and cluster analysis. Statistical analysis was performed in STATISTICA 6 system (Electronic Statistics Textbook, 2013; Ayvazyan, & Mkhitaryan, 2001; Soshnikova, L.A. at al., 1999).

Matrix of Pearson product-moment paired correlation coefficient was calculated on the basis of standardized base. Correlation analysis of indicators of innovative development of regions of AIRR detected the significant (table 2) correlation relations of different pairs of indicators.

Table 2. Category of significance of the paired correlation coefficients.

Category of significance	Non-significant	Weakly significant	Statistically significant	Strongly significant	Highly significant
Level of significance	$p > 0,10$	$0,10 > p > 0,05$	$0,05 > p > 0,005$	$0,005 > p > 0,0005$	$0,0005 > p$
Level of correlation	$r,R < 0,46$	$0,46 < r, R < 0,53$	$0,53 < r, R < 0,70$	$0,70 < r, R < 0,81$	$0,81 < r, R$

In view that significant correlation relation of different pairs of indicators are revealed, so when carrying out clustering of the indicators, correlation linkage distance (1-r Pearson) was used as distance measure of the indicators. Graphical results of cluster analysis of AIRR indicators for the period of 2010-2014 are presented in the dendrograms (Figure 1). Stable (Ward's method, complete linkage method, weighted pair-group average and not-weighted pair-group average) can be considered the formation of 4 correlation relative groups of indicators: F1{12+21+24+31+43}, F2{41+44+45+22}, F3{11+34+35}, F4{23+32+33}.

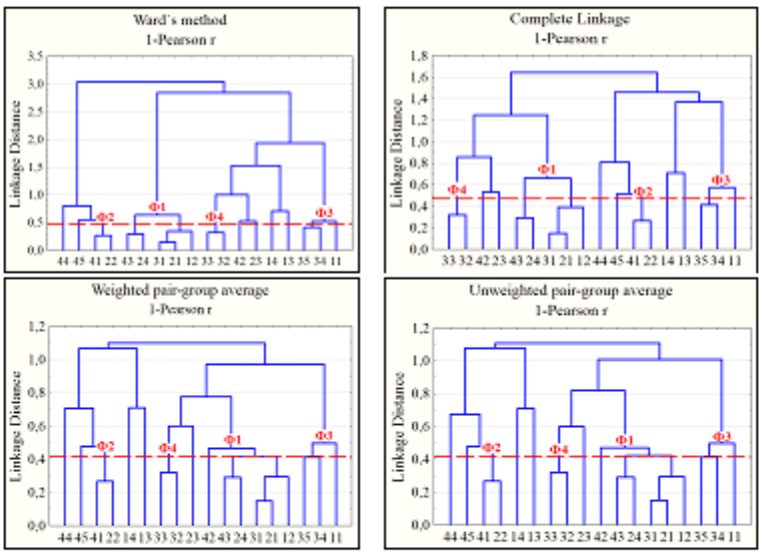

Fig. 1. Dendograms of correlation matrix of the indicators of innovative development of regions of AIRR.

The advantage of cluster analysis is that it allows detecting not only highly significant paired correlations of the indicators inside the major groups but also significant (1 – r ≤ 1 – 0,576 = 0,424 is a critical value for group of 14 regions at level of significance of p=0,05; highlighted at fig.1 by horizontal dotted line)intergroup clusters of the indicators of regions of AIRR, i.e. factors for building base of innovative development of regions of AIRR.

By means of factor analysis 4-factors model of the indicators of innovative development of regions of AIRR is built (table 3). The most significant factor loadings are highlighted by heavy-faced type (partial coefficient of correlation) that allow to interpret the significant factors as per the totality of the indicators. The bottom line shows weighted coefficients of factors. Factor indicators of development of regions of AIRR are given in table 4.

Table 3. Factor loadings of the indicators of innovative development of regions of AIRR.

Variable	F1	F2	F3	F4
11	-0.18	-0.29	0.74	0.23
12	0.84	0.23	-0.19	0.11
13	-0.52	0.41	-0.03	0.49
14	-0.34	-0.42	-0.5	0.35
21	0.95	-0.08	-0.14	0.12
22	-0.24	0.79	0.08	-0.13
23	0.29	-0.52	-0.17	0.46
24	0.79	-0.13	-0.05	-0.15
31	0.71	-0.26	-0.11	0.43
32	-0.05	-0.06	0.22	0.86
33	0.33	-0.03	-0.09	0.80
34	-0.20	0.19	0.83	0.35
35	0.19	-0.06	0.82	-0.30
41	0.05	0.93	-0.08	-0.02
42	0.72	-0.01	0.41	0.16
43	0.85	0.05	0.19	-0.35
44	-0.07	0.67	0.16	0.27
45	0.27	0.62	-0.33	-0.56
Total disp.	4.82	3.21	2.67	3.00
Share of total disp.	0.27	0.18	0.15	0.17

Table 4. Standardized values of factor indicators for regions of AIRR.

Code of the region	Factor 1	Factor 2	Factor 3	Factor 4
1	-1.135	-0.985	-1.248	-0.470
2	0.009	-1.184	0.695	-0.443
3	2.004	-0.075	-0.352	-0.650
4	-0.280	-0.573	1.669	-0.404
5	-1.308	0.422	-0.585	-1.198
6	0.699	-0.883	-0.882	1.058
7	-0.102	0.399	0.789	0.559
8	-0.716	0.139	-0.614	0.167
9	-0.560	1.728	-1.199	-0.847
10	-0.473	1.280	1.139	1.697
11	0.600	1.618	0.619	0.031
12	0.084	-0.744	-1.113	2.058
13	-0.694	-1.167	1.244	-0.618
14	1.873	0.024	-0.162	-0.941

Content and economic interpretation of the factors is represented in table 5.

Table 5. Economic interpretation of the significant weighted factors of innovative development of regions of AIRR.

Code of factor	Detailed explanation of the codes	Weight	Economic interpretation of the factors
1.2+2.1+2.4+ 4.3+3.1+4.2	Share of products of high-technology and knowledge-intensive industries in GRP,% Share of internal expenditures on research and development in GRP, % Internal operational expenditures on foundational research per one organization performing research activity, mln. RUR. Quantity of the developed advanced production technologies per one organization implementing research activity, units. Share of staff engaged for research & development projects, in economically active population, % Developed advanced production technologies, units.	0,27	It reflects relation between financial expenditures on R&D (especially for applied) labour expenditures (staff engaged in R&D) and results of innovative activity in form of development of high technological/knowledge-intensive industries and creation of the advanced production technologies.
2.2+4.1+ 4.4+4.5	Expenditures rate on technological innovations, % Ratio of innovative products, work, services in total volume of shipped products, performed work, services, % Quantity of advanced production technologies used, units. Quantity of advanced production technologies used by one innovation-active organization, units.	00,18	It reflects relation between expenditures on technological innovations, quantity of used advanced technologies and result in form of share of innovative products (products, work, service) in the total volume of products.
1.1+3.4+3.5	Gross Regional Product (GRP) per head, RUR use of results of intellectual activity, units Use of results of intellectual activity by one innovation-active organization, units.	00,15	It reflects the dependence of the main economic result of the region on commercialized technologies (results of intellectual activity)
3.2+3.3+ 1.3+2.3	Total score of regional universities entered the top 100 of the universities in Russia (according to "National rating of the universities"). Coefficient of inventive activity Innovative activity of organizations, % Internal operational expenditures on foundational research by one organization performing research activity, mln. RUR.	00,17	It reflects the efficiency of functioning of scientific and educational complex and its impact on innovative activity of the organizations of the region.
		Σ = 0,77	

For cluster analysis of innovative development of regions of AIRR the Ward's method was selected as the amalgamation rule. The tree diagram shows regions which while "moving" rightwards are being combined and formed in groups (clusters). Depending on selection of the distance it's possible to get the relevant quantity of regions which will be homogenous as per totality of 4 factors: F1, F2, F3 and F4. Along with method of tree-type clustering, K-means method, conducting classification of regions on the basis of set quantity of groups and enable assessing its quality within frames of dispersion analysis is used. Application of K-means method allows consolidating the regions in groups in order to minimize variableness inside the group and maximize variableness between them.

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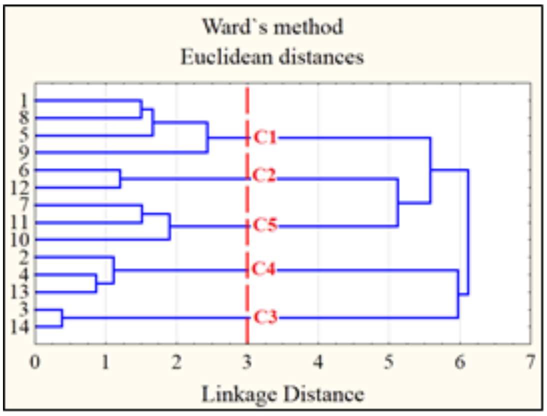

Fig. 2. Dendrogarm of regions of AIRR.

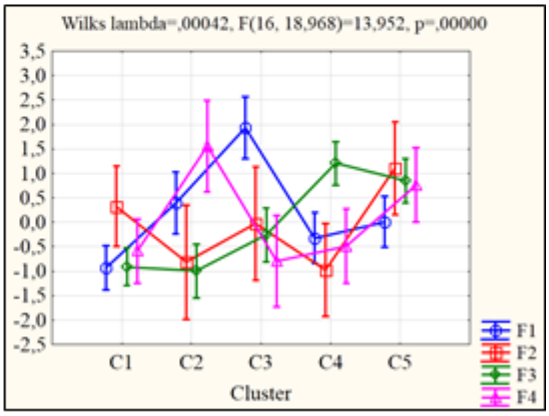

Fig. 3. Line graphs of cluster average with 95% confidence intervals for each factor.

Assessment of significance of differences of the cluster averages in ANOVA is based on comparison of the component of dispersion due to range of variation between groups ($S_{between}$ – sum of squared deviations of group averages from the total averages on AIRR or sum of squared deviations between groups), and components of dispersion due to range of variation within groups ($SS_{between}$ – sum of squared deviations of values of factor indicators for the regions (fig.3) from group averages or sum of squared deviations within groups). According to null hypothesis on equality of the averages of all groups the average dispersion between groups ($SS_{between}$, divided by the relevant degree of freedom (degree of $freedom_{between}$)) will almost match with the average within groups (SS_{within}, divided by degree of $freedom_{within}$). The obtained average dispersions can be compared through F-test that checks whether the ratio of the average dispersion in between groups to the average dispersion within groups significantly more than 1. In the case under study (table 6) the parametric F-test shows that difference between 5 group averages is significant to a different degree: highly significant as per F1 (at level of $p \approx$ 0,00023) and F3 ($p \approx$ 0,00006), and as per F2($p \approx$ 0,0425) and F4 ($p \approx$ 0,0064) –statistically significant according to table 3. Non-parametric (rank) Kruskal-Wallis test moderates these assessments: to statistically significant level ($p \approx$ 0,03) as per F1and F3 ($p \approx$ 0,02), weakly significant as per F2 ($p \approx$ 0,085) and F4 ($p \approx$ 0,051).

Table 6. Results of ANOVA of Grouping of Regions of AIRR, factor-wise.

Factor	SSbetween	degree of freedombetween	SSwithin	degree of freedomwithin	F	Significant difference
F1	11,59110	4	1,408901	9	18,51086	0,000228
F2	8,22232	4	4,777685	9	3,87221	0,042537
F3	11,94621	4	1,053789	9	25,50698	0,000063
F4	9,95933	4	3,040668	9	7,36960	0,006438

Within dispersion analysis (via method of multiple comparisons) the homogenous (which differs at the significance level of $p < 0.05$ not significantly) group of clusters can be identified, arranged in the order of increasing cluster averages (fig.4).

F1: {C1, C4, C5, C2}, {C3}. Where C2 is statistically significant ($0,005 < p \approx 0,023 < 0,050$) differs from C3 by parametric Tukey test and weakly non-significant as per Kruskal-Wallis rank test

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(0,1< $p \approx 0{,}12$); and C1 is weakly significant (0,05 < $p \approx 0{,}052 < 0{,}1$) differs from C2 by parametric Tukey test and by Kruskal-Wallis rank test (0,05 < $p \approx 0{,}064 < 0{,}1$)

F2: {C4, C2, C3, C1}, {C2, C3, C1, C5}. Where C4 is statistically significant (0,005 < $p \approx 0{,}04 < 0{,}050$) differs from C5 by parametric Tukey test and by Kruskal-Wallis rank test (0,005 < $p \approx 0{,}049 < 0{,}050$);

F3: {C2, C1, C3}, {C5, C4}. Where C5 is statistically significant (0,005 < $p \approx 0{,}04 < 0{,}05$) differs from C3 by parametric Tukey test and weakly significant as per Kruskal-Wallis rank test (0,05 < $p \approx 0{,}08 < 0{,}1$).

F4: {C3, C1, C4}, {C5, C2}. Where C4 is statistically significant (0,005 < $p \approx 0{,}024 < 0{,}05$) differs from C2 by parametric Tukey test and weakly significant as per Kruskal-Wallis rank test (0,05 < $p \approx 0{,}08 < 0{,}1$)

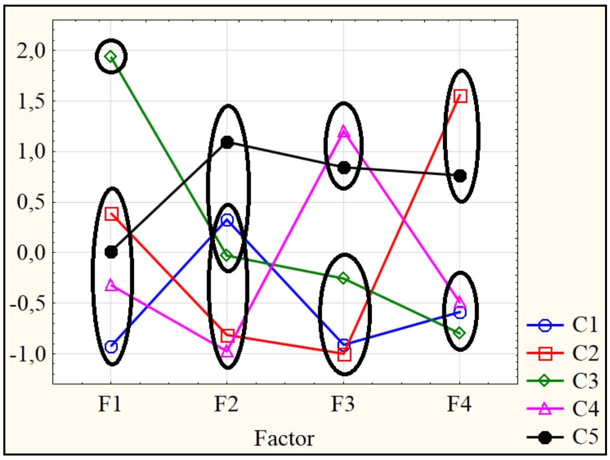

Fig. 4. Homogenous groups of the clusters averages for each factor.

3. Results and their discussion

The carried out classification describes the structure of the cluster models of regions of AIRR in details, carrying out measurements of differences of 5 clusters in nominal scale based on totality of 4 factors. Based on results of clustering, 4 types of groups were identified at the level of 5-cluster model of regions of AIRR (table 7).

Table 7. Typology of regions of AIRR.

Group	Regions
C1	the Altai Territory, Republic of Bashkortostan, the Lipetsk region, Mordovia Republic
C2	Novosibirsk region, Tomsk region
C3	Kaluga Region, Ulyanovsk region
C4	Irkutsk Region, Krasnoyarsk Territory, Tyumen region
C5	Perm Territory, Samara region, Republic of Tatarstan

Type 1 "Industrial innovation-active regions"

- *Subtype 1 "regions with developed medium-technological industries" (*Republic of Tatarstan, Samara region, Perm Territory) they are leaders as per F2, F3, F4; "average performers" as per F1;
- *Subtype 2"regions with developed high-technological industries"* (Kaluga Region, Ulyanovsk region) they are leaders as per F1, "average performers" as per F2, F3, outsiders as per F4.

Under "high-technological" and medium-technological" are understood the industries according to methodology of Rosstat (www.gks.ru/metod/metodika_21.docx): high-technological – manufacture of pharmaceutical products, office equipment and computers, electronic components, equipment set for radio, television and communication of medical devices; measuring instruments, monitoring, control and testing; optical instruments, photographic and film equipment, aircraft planes including space vehicles.

The major source of generation of innovations is an industrial sector. Dominating are the innovative industrial enterprises which are distinguished by availability of their own high-capacity industrial base.

Main structures, dealing with research and development are specialized subdivisions of the enterprises. Developments are carried out according to market demand and are of applied nature thereby the probability of their mass production, sale and consumption at domestic and foreign markets is increasing (elements of model of innovative process G2 "pulling up by demand" are prevailing). They are generator and consumer of the innovations in one. Inputs of the results of innovative activity dominate.

Subtype 1 of the regions is distinguished by emphasis on innovative activity in medium-technological and partially low-technological industries (chemistry and petrochemistry industries, metallurgy, production). They are leaders in innovative activity, level of scientific and educational complex, use of results of intellectual property and advanced production technologies, share of innovative products in total output. They are not characterized by weak (low) indicators.

Subtype 2 of the regions is distinguished by emphasis on innovative activity in high-technological industries (pharmaceuticals, biotechnology, nuclear technology, electronics, automotive industry, ICT, aircraft engineering). They are leaders in share of high-technological industries and expenditures on R&D in GRP, expenditures on applied research, share of staff engaged in R&D in economically active population, generated advanced production technologies. They are not characterized by weak (low) indicators.

Type 2"Industrial regions providing demand for innovations ("market") (Krasnoyarsk territory, Tyumen region, *Irkutsk* region); leaders as per F3, "average performers" as per F1, F4, outsiders as per F2.

Traditionally these are industrial regions the economy of which is based on production, automotive industry, power engineering, metallurgy, and other industries that require high production capacities).

Dominating are the industrial enterprises, which are dealing with their own generation of innovations to a small extent, but they ensure demand for them. Compared to regions of the first type they are not distinguished by high indicators of innovative activity and quality of scientific and educational complex. Inputs of the results of innovative activity dominate.

They are leaders in GRP per head and use of results of intellectual activity, they have low indicators of share in high-technological industries in GRP, expenditures rate on innovations, coefficient of inventive activity, share in innovative products in the total output, generation of the advanced production technologies.

Type 3 "Regions with developed scientific-educational complex" (Tomsk region, Novosibirsk region); leaders as per F4, "average performers" as per F1, outsiders as per F2, F3

The major source of generation of innovations is a scientific-educational complex. Dominating are small innovative enterprises at universities, scientific and research institutions, Special Economic Zone, based on advanced developments which do not involve the significant production capabilities. Main structures involved in R&D are universities, scientific and research institutions, Small Innovative Enterprises. Developments are carried out based on foundational scientific assumption (elements of model of innovative process G1 "technological push" are prevailing). This is a type with updated institution of intellectual property, high inventive and patent activities. Inputs of the results of innovative activity dominate. Leaders in share of innovation-driven enterprises among small enterprises, expenditures on foundational research, share of staff engaged in R&D in economically active population, level of development of scientific and educational complex (total score of the universities), coefficient of invention activity. They have low indicators on use of results of intellectual property in economics.

Type 4 "Mixed (catching-up)" (Altai territory, republic of Bashkortostan, Lipetsk region, Mordovia republic); "average performers" as per F2, outsiders as per F1, F3, F4. The regions which can not exactly be taken relative to any of the above listed type based on indicators of innovation development. They do not have one marked developed sector of innovative economy (industry or scientific and educational complex). As a rule they are distinguished by low results in innovative activity against the other regions of AIRR. Some regions tend potentially to one of the above types, however, for a formal assignment to them a clear course of innovation policy is required with a focus on certain sources of generation of innovation and sector.

4. Conclusion

Thus, regions of AIRR have the objective economic preconditions for implementation of models of the open innovations in form of the complementary types of regions, identified on the basis of peculiarities of their innovative development. Advantages and disadvantages of different types of regions are mutual-leveling when looking at AIRR as a single subject of innovative activity; their peculiarities allow each region achieving an efficient innovative activity through complementarity of resources if each region fulfills its role, defined by type of innovative development. So, industrial regions have possibilities to attract breakthrough technologies, developments; regions with the developed scientific and educational complex have a stable product market for technologies being developed; catching-up (mixed) regions gain further possibilities for development. Such mutual interests and peculiarities of innovative development lay down foundation and are a precondition for implementation of models of the open innovation in AIRR. In view of this the problem of differentiation between regions in the field of innovation can be transformed into an additional source of regional development on the basis of formation of inter-regional innovation policy, the purpose of which is to strengthen and enhance the effectiveness of innovation in all regions on the basis of synergy of use of regional potentials. Development of mechanism of inter-regional innovative policy can further be researched with respect to development of synergetic approach in innovative policy.

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