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PROBLEM OF FORMING BALANCED AGROINNOVATION SYSTEMS: EMPIRICAL EVIDENCE FROM RUSSIAN REGIONS

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Abstract

The paper studied the issues of the balanced spatial development of agro innovation systems of Russian regions using the main indicators of agricultural innovation for 2015-2019: innovative products in crop and livestock production, agricultural machinery, as well as graduates of agricultural universities and employed in the agricultural sector. The degree of concentration of these indicators was determined using the Herfindahl-Hirschman index for the regions of Russia. The results reveal a high of concentration of costs of technological innovations in the agro production, when from 50% to 90% of the costs of the technological innovation in the crop and livestock sectors are concentrated in only 2-3 Russian regions, as well as the absence of dependence on the production of innovative agricultural products on the degree of concentration of indicators and a balanced ratio in the labor market of agricultural specialists in the regions of Russia. To ensure progressive structural changes and enhance innovative activity in regional AIS and increase the efficiency of agriculture, measures are proposed to enhance the balance of AIS components and spillover effects of innovations, resulting in an increase in the efficiency of agro innovation systems functioning.

Key words**:** *Russian regions, innovative activity, agro innovation system, regional development, Herfindahl — Hirschman index*

INTRODUCTION

The relevance of this study is explained by the increasing role of innovation and knowledge flow in the economic development of systems, regions and countries in recent decades and the need to develop approaches to improve the efficiency of innovation in various fields. Today, innovative development is becoming a vector followed by more and more territories and industries. The development of priority sectors of the economy, such as agriculture and food security, is also based on the effective organization of the diffusion and implementation of innovations. To ensure sustainable economic growth in the agricultural sector, a transition to knowledge-intensive agricultural activities is necessary.

For the effective organization of innovation management in agriculture, it is important to develop directions for its balanced development, taking into account spatial and strategic approaches both at the level of the country as a whole and at the regional level. This is possible using the concept of national and regional agro-innovation systems (AIS).

This article continues the search for a methodology for the development of regional AIS and is devoted to the analysis of the factors affecting the improvement of the AIS efficiency. The purpose of the paper is to analyze the balance of AIS in agriculture in regional and sectoral aspects based on data of Russian regions. For this purpose, an analysis of the territorial structure of production and spatial concentration in the regions of Russia for the main sectors of agriculture in terms of the production of innovative agricultural products, the availability of agricultural machinery in the regions and the provision of highly qualified specialists in agriculture was carried out, and the balance of regional AIS for these parameters was assessed.

The main research issue of the article is to analyze the factors influencing the management of innovations in AIS and to determine the degree of consistency of its elements for its effective and balanced development.

The issues of increasing the efficiency of agriculture are typical in all countries. The growing role of knowledge and innovation in the efficient development of agriculture has led to the application of the concepts of AIS and AKIS in the study of agricultural economics. The need to manage innovations in agriculture and the formation of AIS is associated with the limitations of extensive development and the transition to intensive development based on innovations, which becomes possible not only due to the introduction of technological innovations in agriculture, but also the establishment of interaction at all stages between all participants involved in the process of agricultural production. If the regional innovation system produces innovations in the economic system, then innovations in agriculture are an AIS product. The approach from the standpoint of the innovation system in this case allows us to consider the actors of production, infrastructure and institutions, as well as the relationship between them as a whole.

Theoretical analysis shows that AIS is a network of organizations, enterprises, and individuals who are "bringing new products, new processes and new forms of organization into economic use, together with the institutions and policies that affect their behaviour and performance" [9].

An innovation system must be understood not only as elements, but also the connections between them (Lundvall B. A., 1992) [14]. As in any system, the efficiency of AIS is achieved due to the property of emergence: a combination of components allows it to be more effective than these components separately. Researches noticed that "an AIS is a collaborative arrangement bringing together several organizations working toward technological, managerial, organizational, and institutional change in agriculture" (Anandajayasekeram R., 2000) [1, p. 7].

The composition of AIS can differ significantly and different institutions can act as the main generator of innovation, and their interaction with manufacturers can take different forms. AIS can draw on the international, country and regional agricultural research institutions, private agribusiness firms and entrepreneurs, farmers and consumer organizations.

Scientifically, the AIS concept is in a state of renewal and development, as is the case with other territorial innovation systems. Therefore, in the literature there are discrepancies in the interpretation of the term, approaches to the analysis of the phenomenon (Pant, LP, Hambly-Odame, H., 2009) [16], (Spielman, D., Ekboir, J., Davis, K., 2009) [22], Hall, A., Clark, N., 2010) [10].

The literature discusses the differences between AIS and AKIS. AIS is an agricultural innovation system, AKIS is agricultural knowledge and information system. The difference between them in that AKISs focuses on the "generation and diffusion of knowledge, and AISs on the generation, diffusion, and application of knowledge" (Roseboom, J., 2002) [20].

Anandajayasekeram P. notices, that "AKISs, and AISs are soft systems. A soft system is a social construct that does not physically exist but is nevertheless more relevant when studying social phenomena, such as research, knowledge, or innovation" (Anandajayasekeram P., 2011) [1, p.5].

Discussing the difference between these concepts, Rivera WM notes that "AIS did not evolve as a further development of the AKIS framework, but rather as a parallel development which did not build upon the insights of the AKIS literature and the practical experience in applying this framework" (Rivera, W.M., Sulaiman, R.V., 2009) [18, p. 587].

According to Hall et al., the main difference between AIS and AKIS lies in the "greater and more explicit focus of AIS on the influence of institutions (seen as organizations like companies, public research institutes and learning and innovation" [9].

The formation of regional AIS is a complex process that is possible only with an equal contribution of a number of constituent factors, including technological, economic, geographic, social, and institutional.

In this regard, the legislative system, export restrictions, infrastructure, and the development of market relations play an important role in the formation of effective AIS and relations between AIS actors. All these relations undergo a process of reorganization in the process of AIS formation, reaching a certain necessary balance (Leeuwis C., 2004) [13], (Röling N., 2009) [19], (Klerkx, L. at all, 2010) [12]. As a result of this process, a number of actors can be squeezed out of the system of emerging relations (Vanloqueren, G., Baret, P., 2009) [25], (Thompson, J., Scoones, I., 2009) [23], (Brooks, S., Loevinsohn, M., 2011) [3].

At the same time, AIS is at the same time a process of interaction of various actors that create and rely on changes in technology, socio-economic sphere. Such actors have different ideas about how to improve the process of agricultural production.

The issues of AIS formation are widely studied in the literature of all countries. The literature notes that the existing knowledge of how to improve processes in the agricultural sector is often limited in its application due to a weak economic-financial and material base: the high cost of credit, general deterioration of equipment, etc. [2].

The need for the formation of AIS arises earlier in countries with limited land, soil and agro-climatic resources. For example, in Russia in the 90s, after a sharp reduction in support for agriculture, huge areas of cultivated land were abandoned. The problems of AIS formation are especially actualized only at the present stage, when it is required to increase the efficiency and intensification of the economy and bring agricultural production capacities closer to the cities as the main consumers of agricultural products [4, 5].

The formation of the effective AIS presupposes the organization of cluster interaction between participants as a possible condition. Clustering at the local level contributes to the strengthening of regional innovation systems, and the technologies, know-how and innovations created within their framework become the main instrument for the conquest and retention of high competitive positions by the cluster and the region.

An important aspect of the study is the interaction of AIS elements forming in the regions. Some experience has been accumulated about the influence of the agricultural policy of one country on another. In particular, Ulimwengu, J. and Sanyal, P., analyzing the growth rate of agriculture (understood as the result of the agricultural policy), provide evidence that, on average, no country has faced negative side effects due to the agricultural policies of neighbouring countries. On the contrary, on average, each country achieved a 2.5 % growth rate as a result of an overflow from its neighbours [24].

It is also necessary to especially touch upon the issues of the diffusion of innovations and the course of spillover effects in AIS. The diffusion of innovations occurs through technology transfer. Due to its systemic properties, the process of innovative improvement in individual farms can have a spillover effect on other farms in the region, which will contribute to its overall development. The growth in the use of innovations generates significant spillover effects and leads to various direct and indirect effects through the spillover and knowledge transfer [7, 15, 26]. An innovative spillover as an overflow is a consequence of the diffusion and transfer of technologies and innovations in the form of processes of transferring intellectual property, supporting innovative enterprises, and the mutual flow of personnel between industry and the R&D sector.

Geographically, such changes are localized near large agricultural farms around large cities, in which the need to improve the efficiency of the economy is more acute than in peripheral farms. An additional incentive is the financial resources concentrated in large cities, which will make it possible to modernize the production capacities of the agricultural sector. Factors that contribute to the efficiency of AIS are skilled labour, modern agricultural practices, improved seed technology, etc. AIS are formed in regions with different values and ratios of the

following potentials: production potential, investment potential, scientific and educational potential, innovation structure and demand for innovation. Accordingly, an increase in some potential can have a positive effect on the system as a whole. Therefore, we can talk about the spillover effect that occurs in AIS due to the enhancement of its various components, which ultimately leads to an increase in the efficiency of the AIS.

MATERIALS AND METHODS

In this paper, empirical data of agriculture by regions of Russia for 2015-2019 were used as materials for the study. The information of Rosstat was analyzed on the main indicators of agriculture: on the production of innovative products in crop and livestock production, data on the number of agricultural machinery for a number of years, data on the number of graduates in agricultural training areas for each Russian region and information on the structure of employed in the economy by regions of Russia. Thus, the work analyzed the spatial structure of costs for the production of innovative agricultural products in Russia.

Using the Herfindahl-Hirschman Index (HHI), the degree of spatial concentration of agriculture in the regions of Russia was determined. The HHU was calculated according to the formula [11, 17]:

$$HHI=\sum Yi^2, \quad (1)$$

where: Yi is the share of the cost of the i-th type of product in the region from the value for the country as a whole. The Interpretation of the HHI is the following one. The closer HHI is to 0, the more evenly the studied attribute is distributed over the territory, the closer it is to 1, the more significant its concentration in one of the regions.

Also, the share of agricultural graduates trained by universities was compared with the share of workers employed in agriculture in the region. All data were subjected to structural and territorial analysis. This made it possible to analyze the balance of regional AIS in terms of the main parameters: innovative products, technology and equipment, and staffing.

RESULTS AND DISCUSSIONS

As a result of calculating the HHI for the main sectors for Russian agriculture for 2018, the following values were obtained: crop production: HHI = 0.042; livestock production: HHI = 0.029. Thus, the concentration of agricultural production in both sectors is low. The opposite situation is observed in the production of innovative agricultural products (Table 1). The highest concentration of innovation is found in pig and poultry breeding.

Table 1. HHI in innovative agricultural production, 2017

Branches of agriculture	HHI
Growing annual crops	0.294
Growing vegetables, melons, root and tuber crops, mushrooms and truffles	0.377
Breeding of dairy cattle and raw milk	0.185
Pig breeding	0.683
Poultry breeding	0.655

Source: Own calculation on the basis of data from Rosstat [6].

We note that the costs of technological innovation in the cultivation of various crops and the production of livestock products are concentrated in only 5 regions, which is extremely small. There are 85 regions in total in Russia. For example, more than half of the cost of technological innovation in the cultivation of cereals (excluding rice), pulses and oilseeds are in two regions: Tumen Region (32%) and Krasnodar Region (24%). (Fig. 1.)

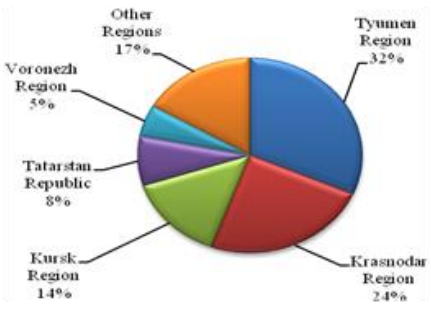

Fig. 1. Share of Russian regions in costs of technological innovations in the producing of cereals (except rice), legumes and oilseeds, 2017 (%).
Source: Own calculation on the basis of data from Rosstat [6].

A similar situation is observed in the cultivation of vegetables, melons, root and tuber crops and mushrooms: three regions account for more than 95% of all Russian costs. These are Belgorod Region (11%), Lipetsk Region (22%) and Volgograd Region (52%). A such situation is with the technological costs of innovations in animal husbandry. So, in the breeding of dairy cattle, the production of raw milk, more than half falls on 2 regions: the Vologda Region (42%) and the Ryazan Region (15%). Attention is drawn to the significant cost indicators in the Siberian regions. For example, from 4 to 7% of all Russian costs are observed in 4 regions: Tomsk, Omsk, Kemerovo and Krasnoyarsk Regions. The Tambov (66%) and Tyumen (28%) regions stand out in terms of costs for pig breeding. Mordovia (68%) and Leningrad (23%) Regions are leading in poultry breeding.
The availability of agricultural machinery in the regions and its use to increase the efficiency of agricultural production is of great importance. In Russia as a whole, there was a decrease in the number of tractors and seeders in the period 2015-2019. Only in some regions there was a positive trend towards an increase in the number of equipment, they are presented in Table 2.

Table 2. Regions with positive dynamics in the number of agricultural machinery, 2015-2019 (%)

Agricultural machinery	Regions
Seeders (more than 5% increase, over 100 seeders)	Republic of Crimea, Republic of North Ossetia-Alania, Altai Republic, Astrakhan Republic, Karachay-Cherkess Republic, Primorsky Region, Tambov Region, Kabardino-Balkarian Republic, Lipetsk Republic, Smolensk Republic, Republic of Sakha (Yakutia)
Tractors (more than 5% increase)	Jewish Autonomous Region, Republic of North Ossetia-Alania, Altai Republic, Karachay-Cherkess Republic, Khanty-Mansi Region, Sakhalin Region, Kabardino-Balkarian Republic, Irkutsk Region, Republic of Adygea, Belgorod Region

Source: Own calculation on the basis from Rosstat [24].

It is noteworthy that the most significant growth in equipment fell not on the regions producing the largest volume of crop production, but on small subjects of the North Caucasus, as well as Asian regions with difficult agro-climatic conditions for growing agricultural products.
Similarly, in the main sectors of agriculture, the production of innovative products is concentrated almost entirely in only two of the 85 regions of Russia (Table 3). This is caused to some extent by the natural conditions for farming, but it also indicates the imbalance in the development of agriculture in the country as a whole.

Table 3. Share of Russian regions in innovative products by sector of agriculture, 2017, %

Sector of agriculture	Regions
Cultivation of cereals	Krasnodar Region (78%), Lipetsk Region (11%)
Growing vegetables	Lipetsk Region (56%), Belgorod Region (20%)
Pig breeding	Tambov Region (82%), Belgorod Region (9%)
Poultry breeding	Mordovia Region (78%), Leningrad Region (20%)

Source: Own calculation on the basis from Rosstat [6].

The level of development of the economies of specific regions directly depends on the level of development of human capital and the provision of the needs of the region with highly qualified personnel, who are the generators and implementers of innovative transformations in the agricultural sector.
In order to implement such innovations, specialized agricultural education is important, since any AIS is formed and functions in specific agro-climatic conditions [3]. Therefore, an analysis of AIS staffing in Russian regions was also carried out.
In any territorial innovation system, special attention in the development strategy should be paid to the qualifications of personnel. Maintaining the correspondence of the number of trained specialists to the needs of the regional economy in them is an urgent task of regional policy. Tables 3 and 4 present an analysis of the number of specialists with higher agricultural education over those employed in agriculture in the regions of Russia, demonstrating the excess and lack of agricultural specialists. The regions were divided into 2 groups: in which there is an

excess of personnel (Table 3), and a shortage of personnel (Table 4).

Table 4. Excess of personnel with higher education in the agriculture over employed by Russian regions, 2016

Region	Excess, times	Region	Excess, times
Saint Petersburg	11.12	Kamchatka Region	1.73
Moscow	8.44	Saratov region	1.65
Sakha (Yakutia)	4.59	Chuvash Republic	1.65
Chechnya	4.22	Vologda Region	1.62
Kostroma Region	3.81	Ryazan Region	1.61
Republic of Buryatia	3.81	Nizhny Novgorod	1.59
Ingush Republic	3.48	Adygeya Republic	1.58
North Ossetia-Alania	3.26	Khakassia	1.57
Moscow Region	3.14	Kurgan Region	1.55
Ivanovo Region	2.57	Rostov Region	1.51
Amur Region	2.45	Volgograd Region	1.43
Kaliningrad Region	2.45	Udmurt Republic	1.39
Ulyanovsk Region	2.41	Kalmykia	1.34
Sverdlovsk Region	2.31	Kaluga Region	1.30
Republic of Tuva	2.29	Pskov Region	1.26
Krasnoyarsk Region	2.20	Yaroslavl Region	1.24
Chelyabinsk Region	2.12	Republic of Komi	1.24
Kabardino-Balkariya	2.04	Smolensk Region	1.23
Republic of Mari El	1.94	Kemerovo Region	1.18
Astrakhan Region	1.90	Omsk Region	1.14
Bryansk Region	1.88	Perm Region	1.13
Republic of Karelia	1.83	Tver Region	1.10
Tatarstan	1.77	Arkhangelsk Region	1.08
Primorsky Republic	1.76	Irkutsk Region	1.03
Altai Republic	1.74	Tyumen Region	1.00

Source: Own calculation on the basis from Rosstat [6].

Regions form Table 4, in which agriculture occupies a large share in the economy, have a shortage of personnel. Many of them make a significant contribution to the production of agricultural products in the country, and are major producers and exporters of crop products. Among them, we would like to highlight the Krasnodar, Stavropol, Belgorod and Voronezh Regions, and the Republic of Dagestan (they are marked with *). We can also notice that all regions from Table 2, which make a significant contribution to the volume of agricultural production in Russia, are regions with disproportions of agricultural personnel from Table 4. Most of the regions with positive dynamics of agricultural machinery also belong to this group. Analysis of the personnel component of AIS in the showed that they are not balanced.

Table 5. Regions, experiencing a shortage of personnel with higher education comparing with employed, 2016

Region	Shortage, times	Region	Shortage, times
Karachay-Cherkesia	0.97	Dagestan	0.63
Voronezh Region*	0.97	Altai Region	0.63
Kirov Region	0.95	Krasnodar Region*	0.62
Novosibirsk Region	0.94	Tomsk Region	0.56
Tambov Region	0.87	Penza Region	0.44
Oryol Region	0.87	Leningrad Region	0.43
Zabaikalsky Region	0.84	Stavropol Region*	0.41
Novgorod Region	0.79	Samara Region	0.41
Kursk Region	0.74	Sakhalin Region	0.40
Orenburg Region	0.73	Tula Region	0.32
Belgorod Region*	0.72	Khabarovsk Region	0.30
Mordovia	0.65	Lipetsk Region	0.24
Bashkortostan	0.64	Vladimir Region	0.15

Source: Own calculation on the basis from Rosstat [6].

For the regions from Table 4, which are significant producers of agricultural products throughout the country, an influx of trained specialists from the regions of the first group from Table 3 with a surplus of specialists for agriculture will be significant. The migration of young specialists to these regions after graduation is a prerequisite for the formation of balanced and effective AIS in these regions. For the development of innovations, constant professional development of specialists, exchange of experience, and tacit knowledge are of great importance. The competencies they bring will cause a spillover of knowledge in the emerging AIS region.

CONCLUSIONS

The analysis showed that there is no dependence on the output of innovative agricultural products on the degree of concentration of agricultural production and agricultural machinery and a balanced ratio in the labour market of agricultural specialists in the regions of Russia. In many regions with

favourable conditions for agriculture, there is no increase in agricultural machinery, costs for agricultural innovations, and there is a shortage of agricultural specialists by universities. On the contrary, it is the regions unbalanced in these parameters that are ahead of others in the production of innovative products. Regions with a shortage of agricultural specialists produce a high proportion of innovative products. This testifies to the imbalance and lack of formation of effective AIS in most regions of Russia. The cost of innovation in the Russian agricultural sector is highly concentrated across regions. From 50% to 90% of the costs of technological innovations in the crop and livestock sectors are concentrated in 2-3 Russian regions, and a significant increase in the cost of agricultural machinery is observed in regions that do not produce the largest volume of products. This testifies to the formation of such a configuration of AIS in the Russian regions, when large agricultural holdings prevail among organizational forms, mainly they introduce innovative technologies due to economies of scale and the advantages of concentration of financial and other resources. However, the share of agriculture in Russia today in GDP is only 3.5%, with favourable climatic and territorial advantages of Russia and the presence of a huge scientific, technological and human potential for its development. In modern conditions of various economic risks and the COVID epidemic, in order to reduce food security risks, there is a real need and opportunity to increase the contribution of agriculture to the GDP. To ensure progressive structural shifts and strengthen the innovative component of agricultural products and improve the efficiency of agriculture, it is necessary to develop direct and indirect measures to stimulate investment and introduce innovations in the agricultural sector, as well as programs to develop migration and adjust training programs for universities and state support for the balance of demand and labour market offers. General management and regulation of the effectiveness of the national innovation system in all sectors are in the area of innovation and state policy and the institutional environment of innovation, which are components of the innovation ecosystem. Modern approaches to innovation shift the focus of innovation policy towards interactions between actors of national innovation systems and consider interactive processes in the creation, dissemination and use of knowledge as a basis for the development of institutional interaction in the dissemination of innovations in regional AIS [8].

The following recommendations for adjusting the agrarian innovation policy are possible:

- to continue “growing” of national food giants and increase the export of agricultural products, but at the same time involve small agricultural enterprises in the vertical chains of these companies through cooperative and contractual forms of interaction;
- to change the model of interaction between agricultural producers, reduce the number of intermediaries between the farmer and the retail network, improve the service for packaging and delivery of products, the coherence and integration of retail chains in the regions of Russia;
-to more actively support the innovative costs of small producers in improving technologies, strengthen the integration of small businesses into food chains;
- to stimulate investments in innovations of small farms, indirect support measures in overcoming internal and external barriers to market entry;
- to introduce measures for the development of rural areas in all regions of Russia, and not individual points of innovation, since modern technologies and innovations by transfer mechanisms will be transferred from large agricultural holdings to numerous small agricultural organizations and farms, giving positive spillover effects [21].

We would like to note, that these provisions of our research of the specifics of AIS in Russian regions are relevant for many agrarian countries with a large extent of territory and the remoteness of the periphery from the centers of economic development. Further analysis of these main components of

innovative development and the phenomena of innovation diffusion is needed from the standpoint of the balance of both regional AIS and at the country level as a whole. The imbalance does not allow the formation of a fully-fledged effective AIS and inhibits the knowledge spillover and the innovations diffusion. In modern conditions, improving the balance of AIS will lead to intensive development of the agricultural complex and will contribute to increasing their efficiency.

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