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PROBLEM ISSUES IN THE IMPLEMENTATION OF INNOVATIONS AND DIGITAL TECHNOLOGIES IN AGRICULTURAL PRODUCTION IN THE CONDITIONS OF NBIC CONVERGENCE

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Abstract

Currently, in the agro-industrial complex, the problem of import substitution of key technological solutions, innovative resources and digital technologies is becoming increasingly important for increasing agricultural production. The aim of the article is to study the prerequisites for accelerating the introduction of innovative and digital products in the agro-industrial complex based on NBIC convergence in the context of digital transformation and improving methods for stimulating demand for them. The article clarifies aspects of the phenomenon of NBIC convergence and its impact on the technological structure of economies. The analysis of indicators characterizing the dynamics of the volumes of innovative goods and services in the context of industries was carried out. An assessment is given of indicators of the digital economy in 2021. It is substantiated that at present the nature of the implementation of NBIC technologies is of a point nature, mainly in the leading agricultural holdings. According to the results of expert surveys, points in growth in terms of the development of digital transformation conditions have been identified. Directions for the development of strategic priorities are proposed in terms of optimizing the cost of introducing digital technologies, increasing digital literacy and competencies of employees, creating mechanisms to subsidize the development of domestic innovative and digital products, as well as stimulating demand for them. The practical significance of the results of the study lies in the possibility of their use in the development of a strategy for the scientific and technological development of Russia.

Key words**:** *agro-industrial complex, innovations, digital technologies, NBIC convergence, indicators, growth points, digital literacy, strategic development*

INTRODUCTION

The current stage of scientific and technological development and the transition to the sixth major cycle of N. Kondratiev is associated with the process of NBIC convergence, which applies to all sectors of the national economy, including the agricultural sector. The process of convergence is distinguished by the blurring of boundaries between individual technologies and an interdisciplinary approach to the development and obtaining of relevant results. In the research environment, information technologies, biotechnologies, nanotechnologies and cognitive science can interact and merge into a single scientific and technological program. Theoretical and methodological aspects of the implementation of NBIC technologies are represented by numerous works in the world and domestic literature. The NBIC convergence paradigm was substantiated by foreign researchers Michael Rocko and William Bainbridge. In the work Converging Technologies for Improving Human Performance, prepared at the World Technology Assessment Center (WTEC), the features of NBIC convergence, stages of evolution, essence and significance in the development of world civilization were studied [23].

Among the works of domestic scientists, it should be noted the works of Yatsishin E.B. [15], Gokhberg L.M. [1]. Emelina V.A. [10] [30].Implementation of NBIC technologies in the context of the digital transformation of Industry 4.0. leads to the development of productive forces and is a new technological order [9].

The main infrastructure link of Industry 4.0, based on the use of fundamentally new digital technologies and digital platforms, is represented by the industrial Internet, through which all participants in the value creation process interact effectively. The emergence of nanochips, biochips and quantum computers served as the basis for the creation of intelligent computers and robots that are widely used in industrial activities [16].

The creation of a fundamentally new scientific and technological base makes it possible to control processes at the atomic and molecular level. In agriculture, artificial neural networks can be used both at the micro and macro levels to predict trends and patterns of development, although it remains quite problematic to choose the most optimal neural network format. A large role is given to innovative computer recognition systems, which significantly increase the efficiency of the use of agricultural machinery. In the research environment, information technologies, biotechnologies, nanotechnologies and cognitive science can interact and merge into a single scientific and technological program, which is a prerequisite for the transition of the agro-food system to an inclusive development model [7].

Currently, digital technologies are becoming increasingly important in the agri-food sector. As a result of the evolution of IT systems, a large number of participants were involved in the integration process. A number of foreign researchers note the need for a new paradigm of digital innovation. In particular, Sjaak Wolferta,*, Cor Verdouwb, Lan van Wassenaera, Wilfred Dolfsmac, Laurens Klerkxd substantiated the theoretical and methodological issues of the analysis and formation of sustainable digital innovation ecosystems in the agri-food sector.

The issues of the implementation of large public-private innovation projects in a number of European countries for the period from 2011 to 2021 were studied. The project participants were engaged in the development of various options for digital solutions, on the basis of which the authors formed the basic principles for the functioning of the digital innovation ecosystems in the agro-food sector and substantiated recommendations for improving the mechanisms for managing digitalization processes [29].

In recent years, the process of digitalization in the agri-food sector has been characterized by an increase in the number of participants, which can be represented by the "digital transformation ladder". On the left side of the ladder, digitalization extends from production and supply chain to food systems [20].

The right side characterizes the expansion of the scope of IT systems from individual applications of farm information systems to data platforms (Ge and Bogaardt, 2015) [12] as well as the data space (Nagel and Lycklama, 202; [5, 21]. The number of new actors is changing towards complex business ecosystems (Wolfert et al., 2021). [28].

Thus, digital transformation reflects significant social and technical and economic changes in the main business operations that affect both production processes and management concepts [4] [19]. The initial stage of digitalization was characterized by the automation of production processes, then the creation of management information systems for farmers took place [17].

Authors such as Fountas, Sørensen [11] analyzed the stages of development, testing and demonstration of digital innovations; the use of such types of digital technologies as the Internet of Things, cloud and mobile computing in the agro-food systems of European countries.

The use of extensive information is a prerequisite for efficient and sustainable food production, as well as raising consumer awareness. It should be noted that the new generation of information systems is characterized by an increase in the number of external users, which complicates

theaggregation of relevant functions for various stakeholders.

A significant role in increasing the efficiency of production and optimizing the structure of sown areas is assigned to the use of genetic algorithms [26].

At the same time, institutional heterogeneity in the use of digital technologies should be noted; due to the high purchase price, they are used mainly by large agricultural organizations of the holding type. In addition, in some industries there is a lack of digital competencies and digital literacy, low susceptibility to innovative and digital technologies.

MATERIALS AND METHODS

The purpose of the article is to study the prerequisites for accelerating the introduction of innovative and digital products in the agro-industrial complex based on NBIC convergence in the context of digital transformation and improving methods for stimulating demand for them.

The methodological basis of the research is legal, legislative acts, works of foreign and Russian authors on the subject of innovative development of the agro-food complex. In the process of research, monographic, abstract-logical, analytical, research methods were used. Regulatory and legislative acts, information from OECD, INSEAD, Global Innovation Index, Rosstat, National Research University Higher School of Economics were used as the information base of the study.

RESULTS AND DISCUSSIONS

One of the most important indicators of the innovativeness of the economy and its industries is the export of technology. In 2021, the export of ICT goods (information and communication technologies) in the whole Russian economy amounted to 2686 million US dollars, an increase of 47.2% compared to 2020, and the export of ICT services over the same period increased by 21.8 % [2].

Russia's positions in the global food market have noticeably improved: in 2022, agricultural exports amounted to 41.6 billion US dollars, an increase of 5 times compared to 2010 [24].

For certain types of economic activity, there is a positive trend in relation to the volume of innovative goods, works and services introduced or undergoing significant technological changes (Table 1).

Table 1. Dynamics of innovative goods, works, services introduced or covered by significant technological changes, million rubles

	Years					2021 by 2017, %
	2017	2018	2019	2020	2021	
Total innovative goods, works, services	3,014,435.1	3,006,565.0	3,156,522.8	2, 925, 556.9	3, 389, 581.3	112.4
of which by type of economic activity: growingannualcrops	9, 446.0	8, 152.6	20, 743.8	21, 714.1	9, 242.1	97.8
animalhusbandry	10, 430.5	16, 211.2	27, 587.1	15, 482.5	25, 319.6	242.7
manufacturingindustries	2, 140, 102.3	2, 077, 459.1	2, 070, 895.3	1, 940, 743.3	2, 346, 795.3	109.7
of whichfoodproduction	240, 423.8	223, 993.3	203, 739.0	190. 758.9	220, 406.3	91.7

Source: Own calculations based on [3].

For the period 2017-2021 The highest rates of growth in the introduction of innovative products were achieved in animal husbandry (242.7%), outpacing the average for the economy as a whole.

However, it should be noted the insufficient

use of domestic innovative developments in the agricultural sector in recent years.

Currently, the trend is improving and more and more domestic products are being introduced into agricultural production. In the Russian agro-industrial complex, about 500 new types of scientific and technical products are annually produced and transferred for the purpose of development.

According to the results of expert assessments, the technologies of no-tillage farming, loose keeping of livestock, as well as biofuel production technologies are recognized as the most in demand in medium-sized agricultural organizations. On the contrary, technologies of precision agriculture, computerization and automation have a low potential for implementation [18].

The use of individual innovative technologies in farms of various categories is shown in Figure 1.

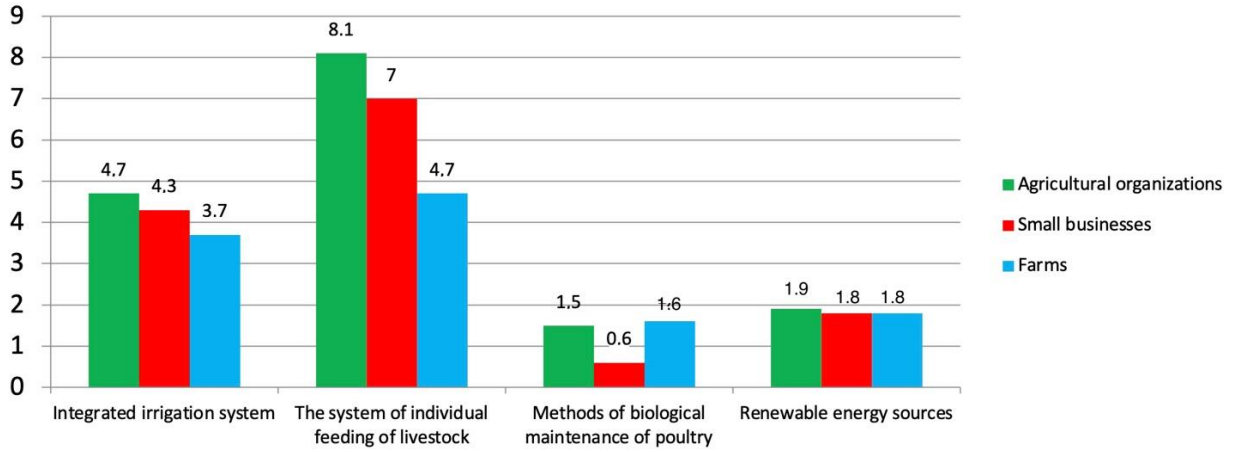

Fig. 1. Share of organizations that used innovative technologies in agriculture
Source: Own calculations based on data [14].

The national platform "Digital Agriculture", which is currently being created by the Ministry of Agriculture of Russia, contains all the necessary information on an industry scale.

Table 2. The main indicators of the digital economy of Russia in 2016-2021

	2016	2017	2018	2019	2020	2021	2021 by 2016,%
Domestic costs for the development of the digital economy from all sources as a percentage of GDP, %	1.7	1.9	1.9	2.2	2.1	2.12	124.7
Number of patent applications for inventions in the field of ICT, units	1977	2270	2063	2702	2457	2684	135.7
Percentageofglobalpatentapplications in the field of ICT,%.	0.33	0.35	0.30	0.36	0.30	0.30	90.9
The share of innovative goods, works, services in the total volume goods shipped, works performed, ICT sector services, %	6.4	6.6	8.0	8.0	7.6	9.4	146.9
Gross value added of the information and advisory services sector as a percentage of GDP	2.9	2.9	2.8	2.9	3.3	3.2	110.3
Share of Russia in the global number of patent applications and inventions in the field of information and consulting services	0.33	0.35	0.3	0.36	0.3	0,32	97.0
Gross domestic costs for the development of the digital economy, billion rubles	3289	3324	3795	4094	4063	4848	147,4
In % of GDP	3.6	3.6	3.6	3.7	3.8	3.7	102.8

Source: Own calculations based on [3].

Currently, according to the National Research University Higher School of Economics [2,3] in Table 2 shows the sector of information and communication technologies in the economy as a whole occupies 3.2% of GDP, demonstrating upward growth trends.

So, in 2010-2021. exports of goods and services related to ICT amounted to 9918 million US dollars, an increase of 2.7 times. In 2017-2021 gross domestic spending on the development of the digital economy increased by 45.8%, and domestic spending on the creation, dissemination and use of digital technologies, as well as related products and services, increased by almost 70%.

The number of patent applications for inventions in the field of ICT, filed by Russian applicants, has increased over 2016-2020. by 24.3%, although the share of Russia in the global number of patent applications for inventions in the field of ICT in the period under review remained practically unchanged.

The number of technology export agreements in 2021 amounted to 6,783, an increase of 61.7% from 2019.

Technology export revenues reached $4,662.7 million. Studies by Russian scientists have shown that the "Knowledge of ICT" indicator has the greatest value on the value of the digital competitiveness index, and the "Conditions for the development of technologies" indicator has the smallest value.

The share of agriculture in Russia's GDP is 4.5%, the level of introduction of advanced technologies (especially digital) in the agro-industrial complex is still not high enough compared to other sectors of the economy.

It is also substantiated that the sufficiency of consumption of basic foodstuffs largely depends on the increase in domestic production [6].

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In recent years, there has been an improvement in the use of digital technologies in agriculture, as evidenced by an increase in the number of agrotech start-ups in 2020–2021 by 30% [13].

The use of certain types of digital technologies is presented in Table 3.

Table 3. Use of digital technologies in organizations of certain types of economic activity (% of the total number of organizations)

	Cloudservices		Collection technologies, processing and data analysis		Digital platforms		Industrial robots / automatedlines	
	2020	2021	2020	2021	2020	2020	2020	2021
Total	25.7	27.1	22.4	25.8	14.7	17.2	4.3	4.4
Manufacturing industry	27.1	28.9	26.5	29.9	14.5	16.0	4.1	5.3
Agriculture	17.8	21.5	17.2	23.3	10.2	9.8	4.2	2.9

Source: Own calculations based on [3].

Digital technologies provide ample opportunities to meet the requirements of the neo-industrial economy. The experts assessed the role of digital agriculture in the process of socio-economic transformation in terms of the following parameters:

- production of agricultural products in the digital environment "from field to counter"; -
- - minimization of intermediaries and trade margins;
- increasing the level of control over the condition and use of agricultural land;
- improving the efficiency of industry management;
- improving the quality of life in rural areas [8].

Growth of profitability of production is achieved due to point optimization of costs. In crop production, technologies for compiling digital maps and planning yields are quite

relevant; technologies for differentiated application of fertilizers.

Of great importance is monitoring the condition of crops and monitoring the quality of the crop. For livestock production, monitoring the health of the herd is important; monitoring the quality of livestock products.

It should be noted that in agriculture, the share of organizations using various digital technologies is much lower. Precision farming and innovative technologies in animal husbandry are mainly used by large enterprises and agricultural holdings.

Agricultural organizations are more actively using parallel driving systems, GIS technologies and industrial robots. In 2021, industrial robots were used by 5.3% of all agricultural organizations, which exceeded the values for the economy as a whole and manufacturing enterprises (4.4% and 2.9%), respectively. The use of robots in dairy cattle breeding can increase profitability by about 15%, and in the case of widespread introduction of robotization, selection and informatization in agriculture, the total economic effect from the use of the above technologies in Russian agriculture will reach 10 trillion rubles.

On the contrary, cloud services, digital platforms and artificial intelligence technologies turned out to be less in demand in agriculture: in 2021 they were used by 21.5%, 9.8% and 2.9% of all enterprises, respectively.

The biggest demand for new technologies comes from large Russian agricultural holdings; the possibilities of digital technologies for small enterprises are significantly limited. Only a few digital products are used by small and medium-sized businesses.

A significant obstacle to the mass introduction of new technologies and products is the lack of IT specialists and the insufficiently high level of digital literacy in agriculture [14].

The most important condition for the multifunctional development of rural space is the activation of investment policy [22].

Stimulation of innovative development is possible on the basis of expanding the forms and methods of interaction between investment policy, science and agribusiness [27].

State support for the digitalization process should be aimed at stimulating end-to-end digital solutions based on appropriate platforms for creating life cycle chains for the production and sale of agricultural products.

The Strategy for the Digital Transformation of Agriculture defines the stages of introducing digital technologies and the algorithm of state support. If at the first stage (2021-2024) it is planned to pilot the stimulation of the introduction of digital technologies by agricultural producers, then at the second stage (2025-2027) the mass application of proven technologies is expected, supported by appropriate measures of targeted state support for enterprises implementing processes and digitalization technologies. At the second stage, intelligent decision support subsystems will also be tested.

At the third stage (2028–2030), an end-to-end system of information support in the field of agriculture will be created. Measures to create digital twins and create digital production in crop and livestock production guarantee a reduction in cost and increase the availability of products by reducing the number of intermediaries in the sale of agricultural products.

The active support of the state will consist in the creation of favorable tax and regulatory regimes; creation of digital infrastructure [25].

To improve the efficiency of innovative and digital potential, the Strategy for Digital Transformation of the Agro-Industrial and Fishery Complexes identifies the following priorities:

-introduction and large-scale dissemination of digital technologies in the main industries and sectors of the agro-industrial complex, including electronic document management systems, artificial intelligence technologies, the Internet of things;

-organizing the production of Russian analogues of imported electronic equipment and software with the provision of the necessary state support;

-creating conditions for expanding the marketing of agricultural products through the introduction of traceability systems for grain and livestock products, accounting for agricultural land, providing access to digital platforms, including small forms of farming;
-increasing digital literacy and developing digital competencies of employees through the creation of new and improvement of existing training and advanced training programs. digital transformation strategy
Improving the opportunities for the introduction of digital technologies by agricultural producers depends both on the level of state support for the digital transformation of the agricultural sector in the form of subsidizing relevant developments and programs, and on the degree of interaction between actors in value chains in the process of generating demand for innovation.

CONCLUSIONS

The article studies the prerequisites for accelerating the introduction of innovative and digital products in the agro-industrial complex based on NBIC convergence, presents the evolution of views on digital transformation issues both in the economy as a whole and in the agro-industrial complex.
Theoretical and methodological aspects of the introduction of domestic innovative products and technologies in the agro-industrial complex are developed and methods for stimulating demand for them are developed.
The analysis of indicators characterizing the volumes of innovative goods and services in the context of industries was carried out. An assessment is given of the indicators of the digital economy in 2021, as well as the dynamics of the use of digital technologies in organizations of certain types of economic activity.
Based on the results of expert surveys, growth points were identified in terms of the development of digital transformation conditions. Directions for the development of strategic priorities in terms of building up digital competencies and stimulating demand for domestic innovative products and digital technologies are proposed.

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