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Digitalization of agriculture: strategic opportunities and risks for Russia

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***Abstract*—The paper contains the summarized results of a study of strategic opportunities and risks of digitalization in the Russian agriculture in a context of increasing of productivity, sustainable development of agrifood system and better advancing Russian food and agricultural raw materials in the global food market. It is established that digitalization of the Russian agriculture is at an early stage of development and the digital processes are considerably depending on the firm size (concentrated on large agro-holdings). It is proved that the threats and risks of digitalization in the Russian agriculture are more serious, than in the developed countries, that is caused by an economic situation in the country, rather low competitiveness of the Russian industry (mechanical engineering, electronics), reducing R&D government expenditures and also deficiency of private investments into digitalization.**

Keywords—digitalization, agriculture, smart farming, productivity, strategy

I. INTRODUCTION

The world today is on the threshold of a new large-scale wave of digital revolution – merges online and offline spheres and emergence of "the cyber-physical world". According to the experts of Boston Consulting group, 99 % of world data is already digitized and more than 50 % has the IP address. Further doubling of data volume will happen each two years [1].

The primary aim of the country is to protect citizens from hunger and malnutrition by enabling sustainable food production. Nowadays new technology and digitization of main processes give the world agriculture a great opportunity to improve productivity. As FAO estimates, by 2050 the global population is expected to increase by almost 10 billion people [2]. In order to feed the planet, it is necessary to produce about 70% more food, but world land resources are limited (farmers can use only 5% more land all over the world). Taking into account growing environmental risks (climate changes) and complicating food policy in leading food-producing countries we can state that the pressure on national food systems is very significant. As more land suitable for agriculture is already farmed, the main way to feed the world is to raise agricultural productivity.

Agricultural development is characterized by a series of revolutions that have driven efficiency, yield and profitability (implementation of mechanization in 1900-1930; the green revolution of the 1960s; genetic technologies from 1990 to 2005). Nowadays digitalization of agriculture could be the most transformative and disruptive of all of these technological changes.

The problem of digitization of agriculture has high relevance for the Russian Federation. In the last decade the Russian agriculture has faced new emerging threats due to significant economic and political changes. In order to adjust to these challenges farmers and food producers have been transforming their business strategy throughout a upgrading of their competitive advantages. So the digital agriculture can become the main tool of increase in productivity and socio-economic efficiency of Russian food producers.

II. LITERATURE REVIEW

The "digital economy" as a scientific category appeared in the end of the 20th century. It was determined by intensive development of the basic digital technologies – the Internet and the information and communication technologies (ICT). These technologies caused large-scale digitalization of many spheres of the economy, and "the digital economy" as an object of a scientific research became an important focus of scientific research all over the world.

The analysis of social and economic development patterns and transformation of techno-economic paradigm of the developed countries shows that the concept of the post-industrial model of development of society proposed by A. Toffler is the cornerstone of most of them. Toffler's book «The Third Wave: The Classic Study of Tomorrow» describes a new concept of socio-economic development and transformation of technological according to which the mankind goes through three types of societies – agricultural society, industrial society, post-industrial society ("Information age") [3].

Studying of digital economy refers to Machlup's analysis of information sector [4], Porat's definition and measurement of information economy [5], Castells' "Information Age" concept [6], and others. Have systematized their works we can note that digital or information economy is a research object of different sciences – economics, sociology, computer and technical sciences.

Jeremy Rifkin is the author of the term "Third Industrial Revolution" (TIR), which is associated with the prevalence

of a fundamentally new technology [7]. Rifkin explores how digital technology and renewable energy are merging to change the world. Recent public debate has become focused on the imminent arrival of a "4th Industrial Revolution". The first researcher who introduced the world to the concept of the Fourth Industrial Revolution (4IR) was K. Schwab. He wrote that the mankind is at the beginning of a revolution that is fundamentally changing the way we live, work and relate to one another. According to him the Fourth Industrial Revolution is essentially different because it is characterized by a range of fundamentally new technologies that are fusing the physical, digital and biological worlds [8].

In Russia problems of a digital transformation also are in focus of attention of scientists. One of the most famous Russian economists Sergey Glazyev formalized change of technological patterns during modern economic development. Results of Glazyev's research revealed change of five technological patterns, including the information and electronic technological pattern that is dominating now. According to Glazyev, new technological paradigm will determine world economic growth in the next decades [9]. Thanks to him the concept of "Technological Pattern" (TP) came into world economics.

Subsequently the concept of Industry 4.0 extended also to the other spheres of economy, including agriculture. At first the role of innovation (including digitalization) has not been given much emphasis in agricultural economics, but since it has become one of the key priorities and critical aspect of modern food systems, many scientists began to study different aspects of digitalization and its impact on food security, agricultural productivity, food waste and so on [10].

The information-based agriculture places the processes of processing and interpreting digital data based on the agricultural production and management systems [11]. S. Shen, A. Batist, and A. Hovard on the International Conference on Agricultural Risk and Food Security (2010) describe digital agriculture as an application of the term "digital earth" and as an expansion of the concept of "precision farming". A digital system in agriculture includes various kinds of data relevant to agriculture and optimal decision functions that help make best decisions in a series of agricultural production and marketing processes [12].

M. Castle, B. D. Lubben and J. Luck wrote that in recent years farmers have quickly adopted precision agriculture technologies. With the availability of digital agricultural tools the rapid accumulation of big agricultural data leads to the demand not just for technology, but also for analysis and advisory services from numerous precision agriculture industry providers [13].

Digitalization of agriculture is also a research object of international organizations. The World Bank Report "Digital dividends" includes the advanced research of opportunities of digital economy [14]. The Global Innovation Index-2017 also was devoted to this problem. "Innovation Feeding the World" is a central issue for environmental sustainability and for the world's social and economic well-being [15]. In 2017 the Food and Agricultural Organization of the United Nations have undertaken a research of agricultural trends and challenges [16]. Also in 2017 the OECD have published the Digital Economy Outlook with the central idea that agriculture could be highly automated in the nearest future and it is only a matter of time before humans are removed from farming [17].

III. METHODS

The methodology of the research is defined by its aim – to review the main current and future digital challenges for the world agriculture and to study strategic opportunities and risks of the digital agriculture in the Russian Federation.

The most important methodological principles and approaches are the following:

- We will use a combination of research methods that allows exploring the problem more effective. The commonly used approaches are analysis and synthesis (study of factors of digitalization), expert method (modeling of long-term global, national and micro-effects of digital agriculture), calculated method and comparative analysis (investigation of the relationship between economic development, innovation level and agricultural productivity).
- Research methodology takes into consideration important characteristics of research object – agriculture, patterns of its functioning and peculiarities of governmental regulation.
- As this paper aims at identifying future digital challenges and their impact for the Russian agriculture, it is necessary to take into consideration the specific conditions of the development of the Russian agrifood sector: continued economic stagnation of the national economy, prolongation of sanctions and food embargo, increasing protectionism, remaining backlog of agricultural productivity against of rising food production.

In order to study the factors and possibilities of agriculture digitalization for the leading food-producing countries, we use such indicators as GDP per capita, food production and food production index, agriculture value added (% GDP), agricultural employment (% of total employment), agriculture value added per worker and Global innovation index. The source of the data is the World Statistics Pocketbook (2017), FAO Statistical Pocketbook (2015), and the Global Innovation Index (2017).

IV. RESULTS AND DISCUSSIONS

Modern challenges such as rapidly growing food demand, reducing incomes of agricultural producers around the world, climate change and depletion of natural resources have fundamentally changed food systems.

As a result of evolution traditional food systems underwent a set of institutional, structural and technological changes therefore traditional systems were succeeded by the modern systems of industrial type. Later food systems began to develop into post-industrial systems connected with expansion of digital technologies at all stages of agricultural value chain. Table 1 shows the comparative characteristic of the types of food systems.

TABLE I. COMPARATIVE CHARACTERISTIC OF FOOD SYSTEMS

	Traditional food systems	**Industrial food systems**	**Post-industrial food systems**
Key activity in a food value chain	Agriculture	Food processing and retail	Research and Development (R&D)
Value chains	Short, local	Long, national	National, global
Agricultural production	Traditional, concentrated in small and medium farms	Industrial, large-scale	Post-industrial smart farming (digital)
Food	Agricultural raw materials, standard foodstuff, distributed via markets or ordinary small shops	Processed branded food, distributed via supermarkets	Organic, processed branded food, distributed via supermarkets and the Internet
Development drivers	Natural conditions (climate, land resources)	Investments, bio-technologies, export-oriented expansion strategies	Innovations, digital technologies, resource-saving technologies
Causes of food crises	Adverse weather conditions, wars, low agricultural efficiency	Food prices shock, trade policy, political changes, climate changes	Increasing food demand (because of population growth, livestock and biofuel production), climate changes

Modern national food systems are very diverse. The differences concern their level of economic development, agricultural output, effectiveness and the role on the world food market.

Some of food systems can both provide national food security and meet the global food demand (developed countries, such as USA, Germany and emerging economies, such as China, India, and Brazil). The food systems of less-developed countries are two types. Food systems of the first type have got natural conditions for agricultural production so they produce and export agricultural raw materials. The other type includes countries which do not have sufficient resource provision and characterized malnutrition and hunger.

The drivers of boost production are also different. While output in less-developed countries has been increasing mostly through the expansion of agricultural areas and labor resources, developed countries have sufficient potential to modernize agriculture with innovations and digital technologies. As for large agrarian countries, such as Brazil, China, Indonesia and the Russian Federation, they have reached total factor productivity growth through extensive and intensive factors and achieved growth rates above their regional average [16].

In order to predict future possibilities of the world food production system we have to compare the level of agricultural output, value-added per agricultural worker and the innovation potential of the country (which determines ability for digitalization).

Table 2 presents the selected indicators characterizing agriculture of 15 leading food-producing countries, as well as a synthetic indicator of innovativeness – the Global Innovation Index. Also it is necessary to match them to the indicator of socio-economic development – GDP per capita.

TABLE II. TOP-15 LEADING AGRICULTURAL PRODUCERS

	GDP per capita (current US$)	**Employment in Agriculture (% of employed)**	**Agricultural production, mln US$**	**Agricultural production index (2004-2006=100)**	**Share of Agriculture (% of GVA)**	**Ag. value added per worker (const. US$)**	**Global Innovation Index-2017/Rank**
1. China	8109,1	27,0	518851	132	9,2	7813	52,54/22
2. India	1614,2	44,3	236540	143	17,0	689	35,47/60
3. USA	56053,8	1,5	215750	111	1,0	69457	61,4/4
4. Brazil	8528,3	15,2	140046	135	5,2	5470	33,10/69
5. Indonesia	3346,5	31,4	60205	139	14,0	1079	30,10/87
6.Russian Federation	9243,3	6,8	46439	120	4,7	5973	38,76/45
7. Argentina	14 564,5	2,0	41146	119	6,0	13176	32,00/76
8. France	36304,2	2,7	38188	103	1,7	84574	54,18/15
9. Turkey	9125,8	19,6	37484	120	8,6	6863	38,90/43
10. Nigeria	2714,5	27,9	36075	116	20,9	4760	21,92/119
11. Mexico	8980,9	13,4	35142	120	3,6	4416	35,79/58
12. Germany	41686,2	1,4	33635	111	0,6	39490	58,39/9
13. Spain	25865,4	3,9	32045	102	2,6	43431	48,81/28
14. Italy	30462,4	3,5	29303	89	2,2	52411	46,96/29
15. Thailand	5814,8	34,0	28642	129	9,1	1195	37,57/51

[a.] Source: FAO Statistical Pocketbook. World Food and Agriculture-2015. Rome, 2015; World Statistics Pocketbook 2017 edition; Global Innovation Index-2017.

Based on the table 2 leading agricultural producers can be divided into 3 groups. The first group includes developed high-income countries with efficient agrifood sector – USA, Germany, France, Italy and Spain. These countries are not agrarian because of small share of the agricultural employment (minimum – in Germany – 1,4 %, maximum – in Spain – 3,9 %), but they have extremely high labor productivity in agriculture (maximum – in France – 84574 US$ per worker). Also they are on the top of the world innovation rating. For instance, in the USA the Global innovation index is 61,4 (4th rank in the world), that along with large agricultural production (3rd place in the world after China and India) means great potential of the American agriculture to be digitalized. EU countries also have a high level of competitiveness on the world food market [18].

The second group consists of emerging economies with medium developed agriculture – China (number one in the world agricultural production), Brazil, the Russian Federation, Argentina, Turkey and Mexico. They are characterized mostly an extensive way of agricultural development, which determines relatively low agricultural productivity. The prospects for future digitalization of agriculture are affected by their innovative potential. The highest Global innovation index is in China (52,54 – 22nd place in the world), the lowest is in Argentina (32,00 – 76th place in the world).

The third group includes emerging low-income economies with ineffective agriculture (India, Indonesia, Thailand, Nigeria). These countries have extremely low labor productivity, but very fast growth of food demand (especially India). Taking into account small probability of the intensive way of agricultural development, low innovativeness and unlikely digitalization of agriculture it can be argued that the food security could be threatened.

So the analysis of data confirms the obvious fact that the developed countries, the leaders in labor productivity in industry, also lead in agriculture. Nowadays industrialized country can feed more population, than agrarian one.

The coming agricultural revolution is revolution Agriculture 4.0 that is changing how the basic principles of agribusiness. Now there is a great opportunity to digitize main processes in agriculture (technology, logistics, management, marketing, finance). According to the paper of Goldman Sachs, implementation of new technologies will increase productivity of the world agriculture by 70 % in 2050 [19].

The Russian Federation is one of the largest producers and exporters of food and agricultural raw materials in the world (e.g., grain, oil seed). Nevertheless, productivity growth is still the result of expansions of cultivated land and more intensive use of inputs; technological change is having a much smaller impact in our country. So the total factor productivity in the Russian agriculture remains relatively low because of slow spread of new technologies (including digital technologies). Russian agricultural producers highly vary in terms of innovation level: most digital innovations in agriculture are led by 'Big Ag' companies (agricultural holdings). As for smaller innovative agricultural technology companies, and top agricultural universities, they don't play much role in digitalization (as in the European countries and the USA).

We emphasize three points of discussion regarding to the digital agriculture in Russia: technology; digital advantages ('digital dividends'); threats and risks.

Modern digital food producers work differently, primarily because of advancements in technology, including sensors, devices, machines, and information technology. Enabling technologies for digital agriculture include [15]:

- Cross-industry technologies – computational decision tools, robots, sensors, digital communication tools. All of these technologies allow using data for better management and lower labor-intensity.
- Field technologies – yield monitors, precision soil sampling, geo-locationing , geographic information systems, auto-steering and guidance, unmanned aerial systems (drones), spectral reflectance sensing, on-board computers and so on.
- Livestock technologies – automated milking, feeding, and monitoring systems, radio frequency ID.

Also the part of digitalization is using new technologies to bring food production to consumers, increasing efficiencies in the food chain. So digital agriculture is not just about precision farming or smart farming. In a digital economy transforming the agribusiness value chain (from field to fork) becomes a significant trend in the agrifood sector.

According to Igor Kozubenko, the Head of the Department of Development and Management of informational Resources of the Russian Ministry of Agriculture, the level of digitalization of the Russia Agriculture can be extended minimum 3 or 4 times. The Russian IT-market which is now more than 360 bln rbl will increase 3-5 times. Full-scale digitalization of agriculture will provide reducing production costs by a quarter: through application of GPS-navigation – 11-14 %, precise soil-fertilization – 8-12 % [20].

In 2017 the state program "The Digital Economy of the Russian Federation" has been launched in Russia. The other program – "Digital transformation of agriculture" – is under review. It was developed by the experts of the Russian Ministry of Agriculture together with the leading agricultural producers. The main objective of the program is digital transformation of agriculture through implementation of digital technologies and platform decisions for ensuring technological break in agrifood sector and increase of productivity at the "digital" agricultural entities twice by 2021.

To achieve this objective it is planned to develop and implement complex digital decisions: "the smart farm", "the smart flock", "the smart greenhouse", "the smart food-processing", "the smart warehouse", "the smart agro-office". The targets of the program are: the share of resources in Big Data – 100 %, the share of smart-contracts with grant recipients – 100 %, the rate of cost reducing – 20 %, the rate of productivity growth – 200 %, the share of investments in digital technologies – 7 % (including made-in-Russia technologies – 5%).

Thus, strategic priorities of digital development of the Russian agriculture can be considered created. But the reality is that very little digitalization has taken place in the Russian agriculture. The reasons are barriers and restrictions of

digitalization. Some of them are global, but the main threats are country-specific.

There are 3 types of threats and risks limiting the process of digitalization. The first threat relates to the macroeconomic and structure problems. Reducing of labor intensity in agrifood sector means laying off unskilled workers and rising structural unemployment. Since digital agriculture is both knowledge- and skills-intensive, it demands the improvement of employment policy and the education system in order to balance labor supply and labor demand for highly-qualified workers.

The second barrier is a resource problem. Adoption of new digital technologies involves high costs, requires public and private investments in R&D. To overcome market failures, Russian government have a responsibility to provide funding mechanisms to stimulate innovation and digitalization in agriculture. Instruments, such as state programs or agricultural grants, need to work more efficiently.

But the private sector also needs to activate investments and inter-sectoral cooperation. In the developed countries not only "big-ag" companies develop new decisions for agriculture. For example, Bill Gates and Richard Branson back startup that grows "Clean Meat"; David Chang (IKEA) and the ruler of Dubai invest $40 million in AeroFarms vertical farming. We think that in Russia it should be the same. The other challenge is that in Russia there is a shortage of digital tools for agriculture because of stagnating domestic mechanical and electronic engineering.

The third problem is a problem of staffing. Now, as Higher School of Economics estimates, the share of ICT-specialists in the Russian agriculture is just 0,5 % of employees, whereas the share of agricultural entities is about 3 %, and the share of value-added in agriculture is 4,4 % [21]. Due to lack human resource skills in ICT the Russian agriculture risks falling behind in its ability to use digital advantages to raise productivity.

Risks of implementation of digital technologies refer not only to the shortage of IT specialists, but also to insufficiency of their knowledge. Some agrarian universities realize advanced courses on digital agriculture, but it is not enough for large-scale digitalization.

One more problem, relevant for the Russian agriculture, is need for re-modeling of mentality and corporate culture. Digital agriculture demands not only high qualification, but also new models of business behavior. Russian farmers are generally more comfortable to think and to manage traditional way than innovative one, therefore they don't establish much demand for digital technologies.

New digital technologies are changing the way stakeholders in the food system. Table 3 presents the key effects of digital agriculture for the world, national economies, agricultural companies and household.

We can see that despite the risks digital agriculture can feed the world, provide the economic growth in the country and ensure the food security. The ratio of benefits and costs of digitalization depends on the level of economic development. The developed countries are in a better position while emerging economies have difficulties.

TABLE III. EFFECTS OF DIGITAL AGRICULTURE

	Advantages ("digital dividends")	**Threats and risks**
World	Increasing level of global food security Resolving the hunger problem	The unevenness of digitalization of agriculture leading to increase of economic differentiation of the countries
National economy	GDP growth Restructuring of agriculture, transition to a new technological pattern More effective use of resources Increase in efficiency of interaction of the state and private sector Possibilities for the analysis of economic and social processes using Big Data	Growth of structural unemployment in the country High government expenditures on R&D and digitalization Radical reorganization of a system of education and training for agriculture Need of an effective system of public and private partnership
Agricultural companies	Emergence of new sources and factors of development of the companies in the long term More effective supply chains Increase in labor productivity and production efficiency Conditions for export expansion Growth of profitability Reducing of food waste along the food chain New forms and possibilities of interaction with the financial sector of the economy	High development costs, resource gap in investment Increasing differentiation of the firms' competitiveness level Shortage of skilled personnel Possible conflict of the priorities of digitalization and organizational culture Complication of technology integration (tradition business processes and new digital processes) Problems of cyber-security
Household	Higher market transparency Increase in economic and physical availability of food (low production cost, internet-shopping)	Employment impacts – risk of unemployment because of reducing labor intensity of agriculture

CONCLUSION

The world agriculture is about to cross the threshold into a new and challenging age. Agriculture 4.0 means the mix of technologies of physical, digital and biological world that creates new opportunities for all economic agents. Digital agriculture seeks to improve efficiency and the potential is to make agriculture productive and allows for better use of time and resources in an efficient way.

The authors conclude that in Russia the problem of digital development in the agrifood sector is urgent because of productivity gap between developed and developing countries. To stay competitive, the Russian food producers need to invest in digital technologies, infrastructure, training programs and alliances that better serve an evolving food value chain. Digital agriculture provides the opportunity for farmers to operate more efficiently, strengthen competitive advantages. Using new technologies can bring food production to consumers, increase efficiencies in the food chain.

Now digital agriculture applications are in the early development stage in Russia. The main barriers identified include macroeconomic and structure problems; resource problems; staffing problems. In order to overcome the

challenges the digitalization in the agrifood sector should be the part of national innovation strategy. Governments must play a key part in solving the digitalization issue in agriculture and to take on a broader and more prominent role than their traditional economic regulation of agricultural development. From our point of view, the Russian government has to improve strategic programs aimed at innovation breakthrough. The main goals of these programs should be the follows: ensure food security and reduce dependency on imports; increase agricultural productivity; become a net exporter not only of agricultural raw materials but processed food, and new technological solutions.

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