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STRESS SCENARIO DEVELOPMENT: GLOBAL CHALLENGES FOR THE RUSSIAN AGRICULTURAL SECTOR

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STRESS SCENARIO DEVELOPMENT: GLOBAL CHALLENGES FOR THE RUSSIAN AGRICULTURAL SECTOR[4]

This paper defines a **stress scenario** as a global or national business development leading to the scrapping of established trends as a result of one or several technological breakthroughs, which can combine with a number of events and factors unfavorable for the global or national economy. The paper presents an analysis of technological shifts in the global agricultural sector focused the impact of these development on the Russian economy. Special attention is paid to scenarios involving deviation from conventional trends, when the imbalance between production and consumption becomes particularly acute while the situation in global food markets changes quickly and significantly with serious consequences for the Russian economy. This remains dependent on developed countries, which are major suppliers of vital resources required for the Russian agricultural sector. Six stress scenarios for the Russian agricultural sector, if certain drivers are triggered, were developed. In contrast to conventional forecasts based on the trends formed in recent years, stress scenarios consider the disruption of such trends, which today are recognized by most experts as the most realistic.

Keywords: stress scenarios, wildcards, black swans, weak signals, technological shifts, agricultural sector, food markets, text-mining.

JEL: C55, O1, O3

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1. INTRODUCTION

Within this paper, a stress scenario is defined long-term trends, which are formed and growing under the influence of unexpected unfavorable external factors with negative consequences. A stress scenario is always harmful, implying the complete destruction of a current global or national socio-economic system or of particular sector of the economy.

Stress scenarios are developed within an approach different from conventional scenario development. They focus on possible situations when conventional tendencies break down, when the supply and demand imbalances become particularly acute or when the situation in global industrial markets quickly and significantly changes with severe consequences for national economies. Stress scenarios are based on traditional scenarios but taking into consideration unexpected unfavorable external factors which pose a threat to traditional industrial development. In other words, stress scenarios join the traditional scenarios of any sector and the threats from the external environment which can change them. As a result, they describe the most unfavorable and destructive directions under the influence of factors that are difficult to forecast. A complex research framework for sectoral stress scenario development was developed in Kuzminov et al. (2017) for the case of energy challenges and the corresponding stress scenarios for the Russian economy.

Under traditional scenarios the authors mean forecasts based on the premise of the preservation of the development of the industrial markets formed in recent years (Rhisiart et al., 2015). Unexpected unfavorable external factors are also called “wildcards”, “weak signals” and “black swans”. Management science uses the term wildcards to describe events with a low probability of occurring and a high potential impact (Saritas & Smith, 2011; van Rij, 2012). In various publications this term is interpreted differently (see review in Kononiuk & Magruk, 2015). Evidence of wildcards can be found in the black swan concept by Taleb (2007), who defines it as an inevitable phenomenon or event having an extreme impact which cannot be affected by targeted efforts and falls outside the range of regular expectations but which can be rationally explained afterwards (retrospective predictability). Popper (2008) defines wildcards as unlikely events which radically change the external context. Weak signals frequently serve as their harbingers, i.e. phenomena or trends which are difficult to perceive. Though the ability to perceive such signals largely depends on the observer’s individual qualities, their weakness remains in direct proportion to the overall level of uncertainty regarding the interpretation of the nature and relevance of short-, medium-, and long-term consequences.

Traditionally, stress testing assessment combined with scenario analysis is applied in empirical macroeconomic models to capture the impact of such stress on the stability of the financial system (among the most recent examples see Dua & Kapur, 2018). These quantitative instruments are increasing implemented in the insurance sector (for agricultural production shock modeling for insurers see Lunt et al., 2016). However, these scenario exercises are extremely limited in their coverage of hypothetical futures (such as technological progress). These models rarely give a description of the whole picture of sectoral and intersectoral development to better respond to and prepare for probable shocks and technological breakthroughs, resulting in blind spots. This research needs to develop special capabilities to see weak signals.

To overcome these shortages researchers have proposed approaches for the accumulation of judgments from different stakeholder groups on possible futures (for example, Meissner et al., 2017 developed the so-called 360^{o} Stakeholder Feedback tool). Considerable efforts have been made to achieve more systematic weak signal detection and use specialist assessments (see the reviews in Rossel, 2012; Saritas & Smith, 2011; and Mendonça et al., 2004; and the theoretical frameworks systemized by Kaivo-oja, 2012; Rowland & Spaniol, 2017; and Derbyshire, 2017).

While quantitative methods of scenario development are subject to the risks of a limited overview of changing parameters, expert assessments have a tendency to be bound by the consideration of all potentially valuable information about the current situation and future trends, not to mention common cognitive and other biases (Tversky & Kahneman, 1974; Tichy, 2004; Ecken et al., 2011).

Finally, text-mining studies of weak signals (for example, Thorleuchter & Van den Poel, 2015; Glassey, 2012; Yoon, 2012) complement this research area, overcoming a number of shortcomings of other methods, although they have their own. Their obvious advantages include the wide coverage of various information sources making evident relevant facts, and the possibilities of cross-source validation makes them reliable. However, special algorithms should be developed for automatic weak signal detection in heterogeneous text arrays. The whole research framework needs to be based on a profound understanding of the phenomena in the form of a structured system of criteria and consistent result description. How can text-mining algorithms provide evidence for stress scenario building? The answer to this question is the main goal of the current study, which combines text-mining techniques with expert knowledge-based methods of stress scenario development.

The driver of stress scenarios is not necessarily the introduction of absolutely new technology. A significant reduction in the cost of existing systems or an unconventional combination of current technologies or their usage in the new economic and institutional conditions, together or independently, can lead to large-scale unforeseen transformations of global markets.

Stress scenario development is important in the studies of the agricultural sector as in the next few decades agricultural and food production are going to face an explosive growth of demand for food due to population increases combined with stronger competition for limited natural resources, first of all land and water (Corsi, 2017; Rosenzweig, 2004; Saritas & Proskuryakova, 2017). To feed the global population (which is expected to grow to almost 10 billion by 2050) food production must increase by 50% compared to 2013 (FAO, 2017). Currently almost a billion people are suffering from famine or food shortages (ibid). Changing diets (mainly because of increased income and improved quality of life of certain population groups) will lead to growing demand for resource-intensive products such as meat and meat products: demand for meat is projected to increase by 50% by 2025, leading to a 42% growth of total demand for grain feed (Nellemann et al., 2009). Agricultural and food producers should be prepared to meet the increased demand for food both in quantitative and qualitative terms. The current situation requires steps to promote productivity growth; agricultural innovators may play a key role in the process, primarily by strengthening collaboration in order to sustainably integrate production, processing, and distribution in the agricultural sector.

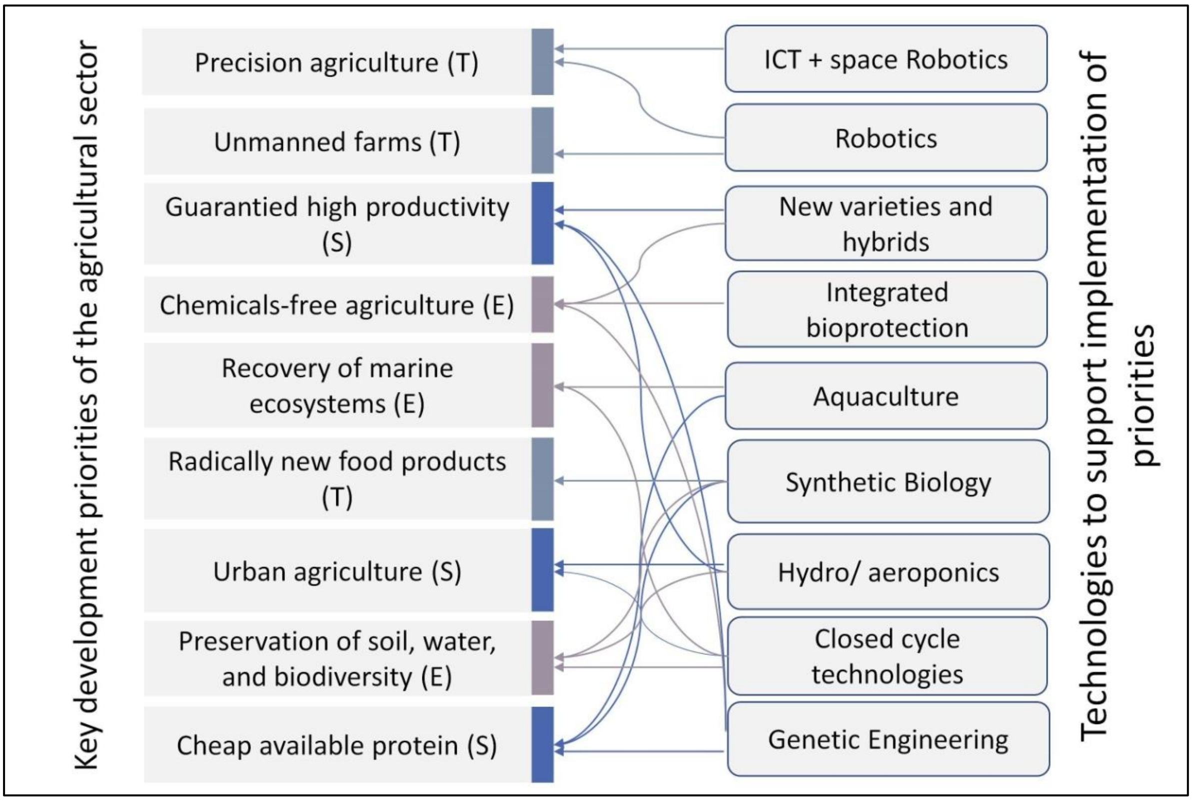
The current productivity growth in the agricultural sector is due to existing and emerging innovations in such industries as food production, automation, and mechanical engineering. Advanced technologies make farms in developed countries “smarter” and, for example, allow the monitoring of crops, cattle, agricultural machinery in real time, implying minimum human involvement. These advances promise increased productivity and reduced environmental impact in the agricultural sector, allowing significant expansion through the development of new previously inaccessible areas and the integration of new industries. Such changes will ultimately lead to a restructuring of the whole agricultural value chain.

Medium- and low-income countries try to increase productivity by applying intensive techniques such as growing more productive animal breeds and crops with improved yields, more resistance to specific local issues (such as droughts, freezing, and soil salination) and with stronger immunity to infection. Processing- and distribution-related innovations are aimed at improving such properties as nutritional value and food safety, consumer convenience, and more efficient use of water resources and infrastructure.

In this context the role of Russian agriculture in the global economy should be analyzed. Historically Russia was a major global food producer. Before World War I the Russian empire was a key grain exporter and had one of the largest cattle inventories in the world. There were periods of famine in the country's history, which seriously undermined the demographic potential of the Russian ethnos. Twice in modern history (in 1917 and 1991) problems with food supply (especially in large cities) became a major factor leading to regime change with catastrophic socio-economic consequences and significant deterioration of the defense potential. Since the early 2000s agriculture in Russia has grown quite quickly (see Annex). The country again becoming a leading global exporter of certain agricultural materials and products (while remaining the biggest net food importer in monetary terms). Currently the Russian agricultural sector displays steady growth and a high resistance to crises (Kuzminov et al., 2018a). The growth of Russian agricultural output (40% in 2005–2015) is comparable with such countries as Brazil and India. Due to increasing public support provided to the agricultural sector, Russian agricultural exports grew by more than 25% 2011–2015. The supply of Russian agricultural products to other countries is growing: in 2016 exports grew by 7,7% in monetary terms and by 12,8% in physical volume. Russia became one of the biggest global suppliers of such products as wheat (a 14% share of the global exports in the 2014/2015 agricultural season), barley, sunflower seeds and vegetable oil. Due to the strongly integrated global grain market, government intervention and the regulation of the domestic market significantly affects the situation in the global grain market. A good example is the embargo on grain exports imposed in 2010 following the drought and the significant losses of the gross croppage in Russia, leading to a significant growth of international prices. Another example of strong integration of the Russian agricultural sector in the global economic environment is the consequences of the retaliatory Russian sanctions for major global agricultural exporters. According to the European Commission's estimates, the combined losses of European Union producers from the Russia retaliatory sanctions exceeded €90 billion. Geopolitical confrontation with developed countries creates major problems hindering the development of the Russian agrarian potential by limiting imports of advanced technologies and hardware.

Hi-tech industries could help Russia make a breakthrough in precision agriculture and engineering solutions in closed-circuit ecosystems may promote development of urban agriculture at the level on a par with the global leaders (Figure 1). However, all this requires a sensible science & technology (S&T) policy, free from the above mentioned negative external factors. A combination of such negative unexpected conditions can disrupt the conventional scenarios for the Russian agroindustry and contribute to a stress scenario within the industry.

Figure 1. The most promising and priority* Russian agricultural sector technologies[5]



* (T) – technological priority (S) – social priority (E) – environmental priority
Source: Higher School of Economics.

In order to be ready to respond to stress scenarios in agriculture it is necessary to predict and integrate into the agrarian policy a list of wildcards and accompanying negative effects. A detailed assessment of the possible impact of wildcards on the Russian agro-industrial complex is considered in the third section with the conclusion section summarizing the potential of the stress scenario approach. The following section dwells on the methodology of our research.

2. METHODOLOGY

Before moving on to presenting more detailed stress scenarios for the Russian agricultural sector we must make a few methodological comments. The net analysis of factors contributing to such scenarios implies that the overall Russian economy remains inertial. In particular, such an assumption means that no radical shifts are expected to happen in the Russian economic structure in the long term. The stress level of the scenarios selected for analysis is specifically assessed in terms of limited access to external markets for major Russian exports. Export-related threats were placed in the foreground of our analysis because of the important fact that the country has achieved a sufficiently high level of food security in most cases exceeding the targets set in the Russian Food Security Doctrine.

Another important aspect of our methodological approach is identifying specific global technology trends[6] which in recent years have largely determined the probability of all stress scenarios considered here. There has been a steady growth of demand for agricultural products in

[5] Technologies which are expected to emerge in the future and make a significant impact on the economic and social development
[6] Major long-term structural changes in economic industries due to S&T development.

recent decades, while the growth of agricultural productivity is slowing due to the long-term effects of the green revolution. The latest advances in information technology and biotechnology have not yet been actively applied in Russian agricultural production. Therefore, we expect that the adoption of technological breakthroughs and innovation could lead to unprecedented changes in the sector.

In order to demonstrate the challenging character of the developed technological stress scenarios, their description is preceded by the presentation of conventional scenarios for the primary Russian food-industry sectors – meat, fish and dairy products. Then the model structure of the developed stress scenarios includes description of a) the contributing factors, which are already happening, b) those which can happen in the future (wildcards), and c) the effects for Russia should such an event occur (stress scenario). To identify areas for stress scenarios and to portray them within this scheme we developed a complex methodological approach combining qualitative and quantitative methods.

Along with foresight research methods – initial desk research and a series of interviews with sector experts (for more details about these steps of this complex research see Saritas & Kuzminov, 2017) – we also applied new methods developed in the field of big data and text-mining analysis. Developed at the Higher School of Economics, the text-mining tools allowed us to foresee the development of technologies and to determine what trends are the most promising and challenging.

The sources for the analysis are heterogeneous and include 2 millions of research papers, 2 millions of patent applications with both full-text data and additional structured metadata, analytical reports by main international organizations and key national players[7], various media and news resources, including all the major technology innovation and venture capital news websites[8]. The tools developed for the analysis include instruments for the large-scale collection, extraction, and transformation of data relevant to agriculture; knowledge discovery; integrated statistical, syntactic and semantic analysis of text and natural language processing (Bakhtin et al., 2017; Kuzminov et al., 2018b).

One of the possibilities of text-mining analytics is the search for weak signals. Evidence for these are provided by means of:

a) the identification of statements with a certain structure and syntactic characteristics from specialized sectoral text arrays relevant to agriculture which are likely to refer to weak signals (qualitative text-mining method). This is based on specially identified linguistic patterns in the sentences, for example, phrases with verbs in future tense or gerund form with adjectives for low probability, hypothetical assumptions or worries which describe transformations, an increase or decrease in values or other forms of dynamics;

b) the statistical classification of particular terms describing trends and technologies identified from the text arrays, which are different in scale and maturity from weak-signal identification (quantitative text-mining method). This is based on frequency statistics in documents: weak signals have comparatively high dynamics, but still comparatively low frequency.

[7] Including the web sites of UN organizations; of them 30 thousand directly related to agriculture, with around 12 thousand documents by FAO, 8 thousand by USDA and from other organizations.

[8] Including among many others: www.independent.co.uk, www.businesswire.com, www.csmonitor.com, www.wired.com, www.enhancedonlinenews.com, www.businessinsider.com, www.ibtimes.co.uk, phys.org, www.cbsnews.com, medicalxpress.com, www.washingtonpost.com, www.redorbit.com, venturebeat.com, www.i4u.com, arstechnica.com, gigaom.com, techcrunch.com, gizmodo.com and so on.

An analogous approach – combining these qualitative and quantitative text-mining methods – was applied in our previous work (see Kuzminov et al., 2018b), but there we proposed the whole framework for stress scenario development on the basis of evidence from the text-mining analysis of big data arrays. In other words, the originality of the current work is the proposal of a systematic framework for stress scenario development by combining the results of qualitative and quantitative text-mining and expert knowledge-based methods (particular components of which were separately described in detail in our previous research we refer to).

The application of the qualitative and quantitative text-mining methods allowed the cross-validation of the results. A list of potential areas for stress scenarios building, i.e. the most controversial topics in agriculture and food market-related analytics: genetically modified organisms (GMO), plague, aquaculture, synthetic food, biological weapons and carbon protectionism. In order to build stress scenarios in these areas and describe them, text-mining methods were also used as a smart instrument for fact searching. Specially developed algorithms were used to search texts for statements containing quantitative estimates of the main relevant indicators, trends, drivers and barriers to the implementation of certain trends, and the potential effects of processes occurring in the sector. This horizon scanning provided us with the opportunity to quickly cover the whole variety of key facts related to the areas studied without the continuous reading of millions of documents. On average, for each topic several hundreds of valuable facts with references were extracted (although still too many to include in the current paper, examples of this kind of results are in Kuzminov et al., 2018b). Finally, we systemized the extracted facts within the developed scheme for the stress scenario descriptions.

The wide coverage of the data sources (including articles, patents, documents of international organizations and the media) allowed us to present a balanced picture of possible radical changes in the agricultural sector described in the next section.

3. THE FUTURE OF FOOD PRODUCTION: TRADITIONAL SCENARIOS VS. STRESS SCENARIOS

Many traditional scenarios of economic development as a whole or of a particular sector are not practically oriented because they often describe the best possible future options. In order to create more realistic future scenarios, it is necessary to avoid conventional assessments and take into consideration the impact of unlikely events. Such an approach allows us to develop scenarios for industry tendencies and to create to scenarios built on a new type of analytics, firstly strategic analytics, based on information technologies (such as artificial intelligence and machine learning).

Analyzing agricultural trends and the challenges the sector is facing is particularly important as there are major problems, which in the long term threaten the food security of not just individual countries but of the whole of humankind. The gap between production and consumption of staples remains insignificant for the horizon until 2030 but in the longer term the picture may change under the influence of external factors (such as global population growth).

Humankind should not just reach the minimum level of output required to close the gap between global food demand and production but get access to the resources required to increase it. To keep developing countries from the brink of famine, grain crops and farm land acreage must be doubled – which is a difficult objective for the next 40 years. The reduced availability of natural resources such as land and water, the proliferation of diseases and pests, the quickly growing urban population – all these factors further exacerbate the problem of getting access to, and making efficient use of, conventional agricultural resources, and encourage the search for new technological solutions. There are a number of technology trends related to global food supply which are expected to replace the conventional production of mainline agricultural products such as meat, fish, and dairy products. First, there is the emergence of artificial meat growing technologies; new types of fishery and aquaculture technologies; and the development of alternative dairy products such as synthetic milk and 3D-printed milk, whose production would affect the environment much less than the current approaches. Such technologies can ensure food production at the necessary level sufficient to meet future food demands.

The traditional scenarios for the primary global food-industry sectors – meat, fish and dairy products – are described here in order to better understand the context for the stress scenarios developed for these sectors.

1. Meat sector traditional scenario

The possibilities for the extensive development of animal farming are very nearly exhausted, due to lack of agricultural lands, the emission of greenhouse gases and other pollutants, and sanitary and epidemiologic risks. There is also the need to increase the output of meat to provide the growing global population with high-quality nutritious food: global demand for meat products is expected to grow.

The answer to all these challenges could be large-scale industrial closed-cycle animal farming, which has a smaller impact on the environment and is much more economically efficient. However, such production technologies are frequently criticized on ethical grounds. Animal rights activists oppose intensive production techniques because animals and birds are frequently kept in closed unlit environments with limited opportunities for movement, combined with the application of traumatic practices designed to maximize conversion rates and weight gains. These arguments significantly affect consumer behavior in developed countries. So-called responsible consumers refuse to buy products not certified as matching certain ethical and other standards. This creates tangible pressure on producers in developed countries: the cost savings are cancelled out by losses due to being pushed out of certain markets, including international ones. Accordingly, animal farmers are actively looking for more acceptable technological solutions.

A radical solution to this problem could be the increased production of artificial animal products, made of vegetable matter with indistinguishable taste and nutritional properties. Another emerging trend is the technology for growing animal tissue in artificial environments (the so-called cultivated meat, or test-tube steaks (Bhat, 2015; Datar & Betti, 2010; Hocquette, 2016)). This is due, firstly, to the very low efficiency of artiodactyl ruminant farming. Producing 15 grams of beef protein takes 100 grams of vegetable proteins. Accordingly, pastures take about 30% of the usable land area worldwide, while farmland uses only 4%. Secondly, synthetic meat grown from animal cells is considered to be safer and healthier because products with a better fat/acid balance can be produced in laboratory conditions. The production of vat-grown meat is estimated to take 35–60% less energy, 98% less land, and emit 80–95% less greenhouse gases than conventional meat production.

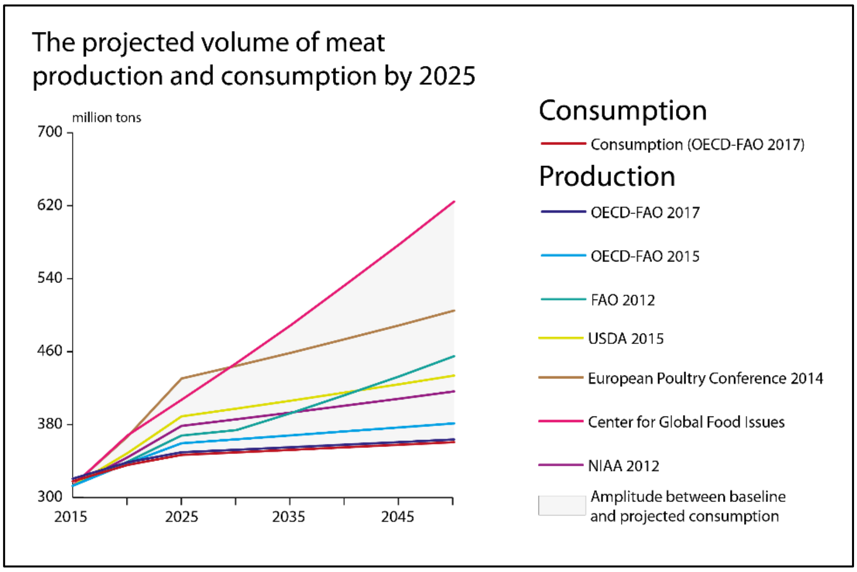
The main challenge[9] for cultivated meat production is its high cost. Even though these technologies have a long way to go to reach the commercialization stage, startup companies specializing in the area have already attracted tens of billions of dollars in venture capital and are expected to start commercial exploitation within the next decade. In 2013 biologists made the first burger with artificially grown meat; the cost was $325,000. The subsequent development of

[9] A major problem of socio-economic, science and technology, environmental, or other nature, dealing with which on national or global level requires an integrated approach.

relevant technologies has greatly reduced this figure; currently a kilo of artificial meat costs $80, and a burger $11. Thus in 4 or 5 years the costs have dropped by a factor of 30,000. At the end of 2016 the production cost of half a kilo of minced beef was $3.6, i.e. almost 10 times cheaper than vat-grown meat. According to researchers and the founders of artificial meat startup companies, in 5–10 years artificial meatballs and hamburgers will be sold in stores at moderate prices. The overall global synthetic foods market is expected to reach 116 million tons by 2050.

Vat-grown meat should not be expected to become available in Russian shops very soon: the relevant demand is forecasted to emerge only in 20–30 years, actually reaching the required consumption level by 2050. In Russia, where per capita consumption remains much lower than in several other countries, price remains the key factor for consumers – as opposed to ethical issues animal welfare. Therefore, this trend is unlikely to become relevant in Russia in the near future. In the long term, however, the country risks facing an unbridgeable technological gap in the field of new, humane animal farming technologies and industrial animal farming generally.

Figure 6. **The gap between global meat consumption and production forecast for 2050**



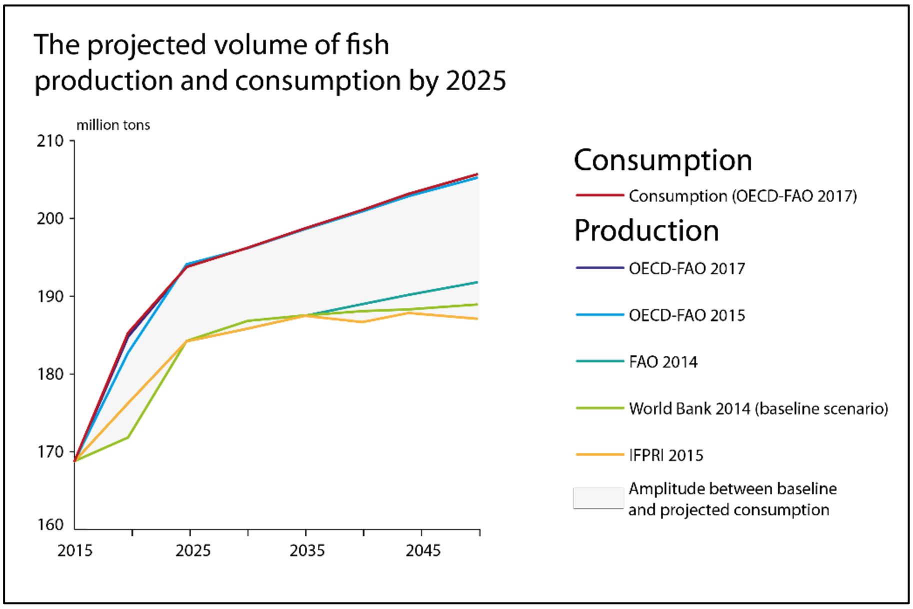
Source: Higher School of Economics.

Finally, considering the impact of all new technologies on the livestock industry, the global production of meat is expected to grow and may reach almost 500 million tons a year in 2050 (Figure 6).

2. Fish sector traditional scenario

Global demand for fish is expected to reach around 200 million tons by 2050 (estimates vary). The development of fishing technologies and increased consumer interest in seafood means that 90% of sea fishing potential is being actively used now. Annual economic losses, or profits missed because of the inefficient organization of international fisheries are estimated at $50 billion. This leads to the depletion of resources: in many locations recovering wild fish populations may not be possible. Even under the most favorable fish production scenario (Figure 7), meeting global demand for fish would become problematic by as early as 2030: the catch will remain unchanged while the demand of the rapidly growing middle class, especially in China, is going to significantly grow. Increased production of fish protein provides a major solution for the global food supply problem. According to the UN Food and Agricultural Organization (FAO), fish and seafood provide 17% of animal proteins. Limitations for increasing the catch, combined with the steady growth of demand for hydrocole foods (one of the cheapest sources of animal proteins) led to the rapid development of aquaculture, or fish breeding. According to the FAO (2016), during the last 20 years global aquaculture output has tripled reaching 78 million tons in 2014 – the fastest growing segment of the global food market. By 2030, 52–60% of global fish production would come from aquaculture or more than 93–96 million tons in physical terms.

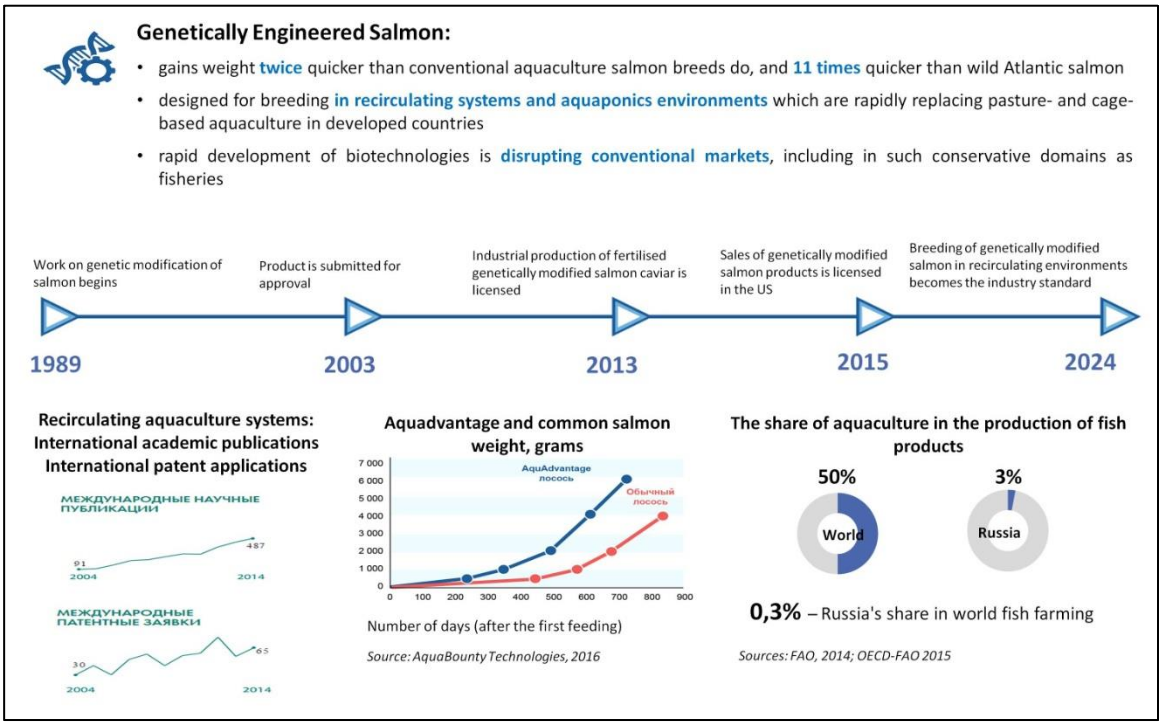
Figure 7. **The gap between fish consumption and fish production forecast for 2050**



Source: Higher School of Economics.

To increase aquaculture output companies will start breeding fish in giant reservoirs specially equipped to accelerate the growth of fish: filled with water enriched with nutrients, at controlled temperature and with specific bacterial content. This will help to recover currently depleted natural fish reserves (Figure 8).

Figure 8. **Development of aquaculture (by the example of genetically modified salmon)**



Source: Higher School of Economics.

A major way to radically increase production is recirculating aquaculture systems, i.e. breeding fish in completely closed controlled environments with zero emissions, the filtration of water, and using by-products as raw materials for making consumer products. This approach is particularly important due to the danger of epizootics and parasitotic infections (some of which are dangerous to humans) inherent to lagoon, pond, or pasture-fattening fish breeding.

3. Dairy sector traditional scenario

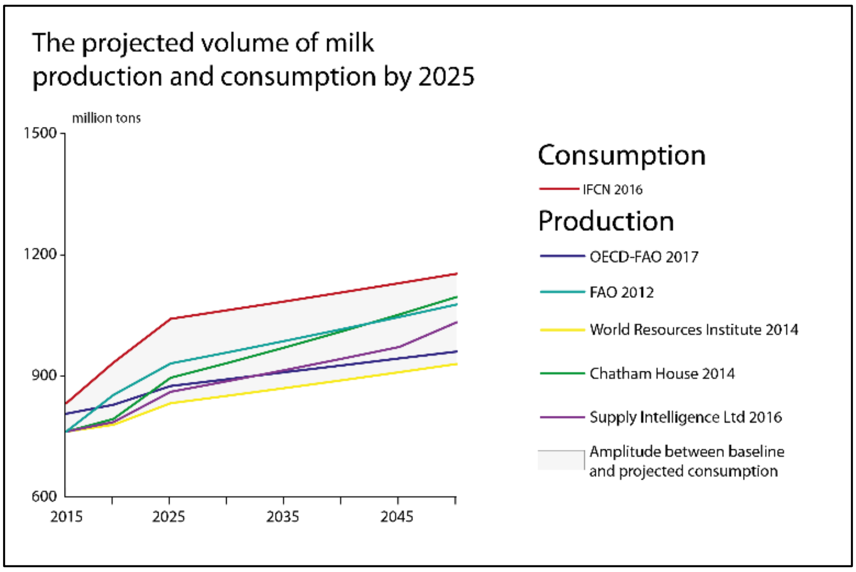
Global demand for dairy products is expected to grow but stepping up milk production increases the environmental costs. Scientists believe people will not be able to avert disastrous global warming if they do not stop producing certain foods at the current level: milk and cheese in particular. The reason is that dairy farming produces particularly high greenhouse gas emissions (Azevedo, 2018). On the whole, agriculture and food production are responsible for about 25% of global methane and carbon dioxide emissions. Animal farming produces about 15% of the total amount of such emissions, but dairy products specifically in that respect are only slightly behind metallurgical factories and coal-powered power stations.

A possible solution is cow milk alternatives such as drinks made from cereals and nuts. These, combined with a general upgrading of agriculture, would help to at least halve emissions negatively affecting the climate (according to some estimates, reducing them by 75%).

There are, however, more radical ways to step up milk production. Currently this industry is moving on towards the direct industrial synthesis. Bioengineers have already created synthetic milk based on a special yeast strain indistinguishable from cow milk. Such milk can also be enriched with additives such as vitamins, minerals and proteins (casein and serum proteins). The resulting product would be particularly suited for people allergic to lactose. Certain synthetic milk production projects involve the application of special proteins printed with molecular 3D printers. Synthetic milk will be able to compete with natural milk on equal terms as early as by 2030.

Taking into account the impact of all the new technologies in the dairy industry, global milk production is expected to reach 1 billion tons in physical terms (Figure 9).

Figure 9. **The gap between milk consumption and milk production forecast for 2050**



Source: Higher School of Economics.

4. Stress scenarios

The above traditional scenarios may be significantly altered should wildcard events actually happen. For realistic advanced forecasting, it is necessary to consider the external factors which can be classified as wildcards and which could substantially change the traditional scenarios. These factors can be classified as existing trends that the economy already faces today, and emerging trends that the economy may face in the future. Such weak signals could transform the industrial landscape in the long-term and should be taken into consideration within S&T policy development for the industry.

Before observing the stress scenarios and the related wildcards specific for the Russian agroindustry, it is important that we find the “best” and “worst” stress scenarios according to how effectively they are able to cope with certain challenge for the industry. Stress scenarios that are based on radically new technologies in terms of economic agriculture results (the value of production, etc.) may have a relatively positive effect, bringing significant effects into the related government policy directions. Here the main government strategic priority could be, firstly, the rapid adaptation of such critical new technologies. For stress scenario development considering external threats, a more complicated strategic policy is needed. For traditional scenarios, the baseline usually does not consider such radical changes at all, so this is the key difference in traditional and stress planning. Similar unexpected external factors may be considered in optimistic and pessimistic traditional scenarios.

The list of wildcards and the six associated stress scenarios for four sectors of the Russian agribusiness are described below: plant growing, livestock, fisheries and the food industry. In addition, two stress scenarios related to the agro industry as a whole were developed; they describe the future through the biological weapons and carbon economy.

1. PLANT GROWING: GLOBAL TRIUMPH OF GMOs

New technological breakthroughs in developed countries render Russian grain, sugar, and forage exports uncompetitive.

Existing contributing factors

While the ban on using GMOs in agriculture remains in place in Russia (Osmakova et al., 2018), developing countries are adopting ambitious biotechnology development programs (i.e. China).

Potential contributing factors

1. The UN approves a number of agreements to combat climate change, reduced biodiversity, environment pollution, and famine in developing countries. The international community recognizes that one of the tools for accomplishing these objectives is the widespread application of GMO plants.
2. Simultaneously the US starts a more aggressive policy to promote economic growth. This results in the explosive growth of investments in biotechnology research and other high-tech industries and causes capital to flight from Russia.
3. A new dotcom bubble based on next-generation search engines, social networks and cloud services emerges and bursts. Venture capital flees IT industries into areas such as bio, nano, and space, including agricultural biotechnologies.
4. Organic GMOs become a new marketing trend in the organic foods market.

Wildcard effects for Russia

New players enter agricultural markets where Russian exports (grains, sugar, sunflower seeds and oil, certain forage crops) traditionally go, some of them from developing countries. This results in reduced volumes of and revenues from Russian agricultural exports. Russia can no longer compete, in value terms, in the traditional agricultural export segment (the costs of growing GMOs are $10–15 per hectare less than growing conventional species). Reduced export revenues for agricultural producers who can now only sell domestically protected by standards and non-customs regulation, lead to their reduced investment potential, a deterioration of the technological basis and declining productivity. A lack of competitive groundwork in genetic engineering negatively affects the provision of genetics-related information support for conventional selection practices; the country’s dependency on imported seed materials worsens. Russia faces a choice between importing genetically modified forage crops or gradually winding down its animal farming industry, accompanied by a growing share of imported meat on the domestic market. A black market for genetically engineered seed materials and products emerges in Russia. The situation with the actual application of GMOs, especially by small producers, gets out of control. The increased production of genetically modified timber of traditional Russian varieties by other countries leads to a decline of the Russian forest industry and the closure of major pulp and paper mills. Russia becomes a net importer of timber-based products.

2. ANIMAL FARMING: PLAGUES

Major epizootics wipe out most of the meat livestock in Russia and the Eurasian Economic Union countries.

Existing contributing factors

Climate change leads to the proliferation of natural focal livestock diseases into areas where animals have insufficient immunity to pathogens uncommon in these climatic zones. There are also a number of other factors that aggravate animal mortality. People increasingly breed animals on their own land plots without adequate sanitary monitoring or control, which makes such breeders a major source of dangerous disease agents, potentially threatening large producers and the human population via zoonotic infections. The sanitary norms for disposing of dead cattle are increasingly disregarded; the meat of animals that have died of diseases is sold to wholesalers using various "grey" schemes instead of being properly disposed of. This creates risks of proliferation of extremely dangerous zoonotic infections among the population and the emergence of mass epidemics in large cities. The proliferation of new practices regarding the application of antibiotics (including those to boost weight gains) is a factor contributing to the emergence of certain disease strains (including zoonotic ones) resistant to existing antibiotics. The systemic introduction of traces of antibiotics in the human organism increases the risks of uncontrollable epidemics provoked by epizootics. Inadequate zoosanitary control at customs borders create threats[10] of importing contaminated meat and live animals, including those with diseases against which Russia has no vaccines or medicine. New technologies like industrial zero-grazing animal farming at super-large complexes increases economic risks associated with a possible catastrophic loss of livestock due to outbreaks of diseases. Generally, insufficiently strict quarantine policies in regions where epizootic outbreaks were registered hinder the efficient localization of epizootics.

Potential contributing factors

1. The melting of the permafrost in the Russian Arctic leads to the activation of pathogens which have lain dormant in old tundra and north taiga cattle graves.
2. Losing Russia's own S&T basis for the production of active antibiotic and antivirus components and vaccines makes the country extremely vulnerable. If geopolitical rivals decide to cause it harm, in a situation when the epizootic wildcard does occur, they may impose a coordinated embargo on supplying drugs, motivated by the risk of the disease proliferating in their countries and therefore requiring a sufficient backup supply of medicines. This scenario may be seen as a form of biological warfare.
3. Attempts by Russia's geopolitical rivals to use crypto-biological weapons against the country's agricultural potential and population cannot be ruled out. This would undermine its economic and demographic potential, force it to abandon strategic deterrent weapons and dismember the country.

Wildcard effects for Russia

The most likely epizootic wildcard events for Russia are the total loss of poultry and pig populations, which are, along with fisheries, key sources of cheap animal proteins. As a result, the potential total practical dependency on imported pork and poultry for at least 10–15 years and sharply reduced annual per capita meat consumption, from 75 to 40 kilos or less. Meat products become rare treats. The rural population kill off their livestock to avoid its confiscation

[10] Factors hindering accomplishment of socio-economic and science and technology objectives.

for sanitary reasons by government agencies. A high probability of mass disobedience and revolt in rural areas. For a major epizootic hit on the poultry industry, the proliferation of epidemics among the human population as a result of the transfer of zoonotic infections is also likely. The consequences include the death of tens to hundreds of thousands of people, primarily in the country's largest cities from epidemics; the undermining of human resources and in major economic centers; a sharp increase of emigration from the country lasting at least several years. The shortage of meat products will lead to a reduced birth rate and life expectancy and an increased infant mortality rate. All of these lead to economic losses on the scale of hundreds of billions of dollars.

3. FISHERIES: THE END OF FISHING

The aquaculture of genetically engineered fish renders the Russian fishing industry uncompetitive

Existing contributing factors

The obsolete Russian fishing fleet combined with a lack of incentives to build new fishing vessels at Russian shipyards leads to significantly increased running costs in the industry, which reduces its competitiveness. The success of commercial mariculture and aquaculture in developed countries pushes Russia out of its traditional, highly profitable market niches (such as sturgeon and salmon caviar, salmon, crabs) and hinders the growth of new segments (such as oysters, scallops, sea urchin caviar). Natural factors (an insufficiently warm climate) impede the development of aquaculture and mariculture in Russia. The lack of relevant commercial Russian technologies combined with the weak ruble makes this industry even less competitive. Its role is limited to supplying the cheapest animal proteins for specific population groups (carp, silver carp for school canteens; food supplies for the army; possibly food coupons to provide targeted support to the most vulnerable social groups).

Potential contributing factors

The logic of the economic situation may make renting out quotas for catching Russian marine bioresources to Chinese, Japanese, and European companies much more profitable than granting such quotas to Russian firms.

1. Selection and genetic engineering advances lead to the creation of new, domesticized fish species with much higher nutrition value and better tasting than similar wild species (e.g. trout).
2. The production of fish flour from cheap, fast-growing (mostly tropical) fish species becomes a much bigger industry than it is today, pushing out various vegetable-based types of forage for animal farming in various countries including Russia.
3. Aquaculture's share of fish protein production in developed countries (and in developing ones with warm climates) keeps growing from the current 48–50% to 70–80% in 20–30 years.
4. Natural and anthropogenic, cyclic and irreversible climate change, along with changes in ocean circulation patterns lead to a significant decline in industrial fishing reserves of traditional Russian species (e.g. Alaska pollack), while reserves of other (non-commercial) species may increase.
5. Further pollution of the seas by polymer and plastic waste aggravates bio-accumulation and bio-magnification, rendering the output of the Russian fishing industry unpalatable. Under one scenario, minor changes in the catch properties lead to a significant alteration of consumers' perception of such products as unhealthy, triggered by aggressive media campaigns by environmental groups or funded by Western governments. This may very negatively affect

Russian fishing exports (including Alaska pollack exports to the US and other countries), and undermine the industry's key markets.

6. The introduction of new international standards for ship emissions and discharges in the MARPOL convention[11] may become a tool for limiting access of the Russian fishing fleet to a number of traditional fishing areas in international waters (first of all, in the North Atlantic).

Wildcard effects for Russia

Fishing output dropping from 3,5–4,5 million tons a year to 1–1,5 million tons and the significantly reduced availability of fresh northern fish (i.e. species with higher fat and nutritional content) to consumers. This may lead to increased poaching by Russian citizens, and increased illegal, unreported and unregulated fishing in Russian territorial waters by foreign ships targeting the most valuable and endangered fish and seafood species (sturgeon, crab, etc.). Another consequence is the reduced production of Russian mixed fodder due to its replacement by imported fish flour. The total degradation of civilian shipyards, the catastrophic growth of unemployment, criminalization, the disruption of political stability in remote isolated fishing towns and villages in the European North and in Far Eastern costal areas.

4. FOOD INDUSTRY: TEST-TUBE STEAKS

Synthetic foods eliminate the demand for agricultural land.

Existing contributing factors

Low energy prices, cheap credit, surplus labor due to global population growth lead to unprecedented rates of technological modernization in developing countries, while Russia remains in a prolonged structural economic crisis. Problems such as soil degradation, weed and pest resistance to modern insecticides and herbicides lead to increased forage costs for conventional animal farming.

Potential contributing factors

The increased application of technological innovation in industrial production and the declining prices of new products due to advanced innovation and venture infrastructure in developed countries has led to the accelerated commercialization of "vat-grown meat" production technologies, with their application horizon shifting from 2030–2040 to 2020.

1. Developing countries, experiencing acute demographic and food supply-related problems, begin to promote the import of new products and technologies[12] and stop buying more expensive natural meat, including from Russia.
2. Environmentalist and other civic groups sharply step up campaigns against the consumption of natural meat for humane reasons, the need to reduce emission of greenhouse gases, and biosecurity considerations.
3. Governments of developed countries and the owners of new technologies launch an aggressive media campaign, in particular via charity foundations to promote the new types of meat products.
4. The first serious successes of leading European institutions in synthetic meat development (including those of the Wageningen food cluster) lead to a sharp increase in investment in this

[11] International Convention for the Prevention of Pollution from Ships.

[12] Technologies expected to be created in the near future according to authoritative Russian and international forecasts and analytical documents.

area in the US, Asia and South America. Fast-growing startup firms emerge, changing the structure of conventional animal protein markets.

5. The introduction of new international regulations aimed at reducing the carbon intensity of the global economy burdens the plant growing and animal farming industries with new carbon taxes. Carbon protectionist measures are applied against countries that do not take such steps in the WTO framework.

Wildcard effects for Russia

A sharp increase of cheap synthetic meat imports into Russia combined with limited opportunities to protect the domestic market due to membership of the WTO negatively affects the country's balance of payments. Investments in the Russian animal farming sector oriented towards promoting exports become excessive and lose value. Unemployment grows by at least 0.5–1%, becoming predominantly structural. Meat production by small farms and individual producers practically stops. Technophobia and the rejection of new products in rural areas lead to the growth of shadow animal breeding on individual land plots. A few large more efficient agricultural holding companies remain competitive but have to rebrand their products or adopt new marketing strategies (e.g. describing them as "semi-organic" food). Reduced forage consumption due to a decline of animal farming results in various interconnected multiplicative effects spilling over into plant growing, undermining the foundation of the sustainable development of rural areas. Increased consumption of synthetic meat leads to unpredictable consequences, including the emergence of new, previously unknown human diseases and pathologies whose origins may not be quickly identified. Increased access to alternative animal protein production technology leads to a sharp increase in the activities of environmentalist and animal rights groups (including those funded from abroad). All these factors result in a new, dangerous social divide, outbreaks of extremism and terrorism (including bioterrorism) on new ideological grounds.

5. THE WHOLE AGRICULTURAL SECTOR: BIOLOGICAL WEAPONS

Contaminated food supplies lead to emergence of new human diseases.

Existing contributing factors

The activities of biohackers over the last ten years have become increasingly well-organized (occasionally even regulated by special legislation). There are several factors influencing this trend. First, alternatives to expensive biotechnology equipment are becoming increasingly available; such equipment can be inexpensively procured via the internet. Biohackers set up small "shared equipment centers" where facilities are available for a small fee. Even affordable portable biolaboratories can be obtained. Secondly, materials for biotechnology research (i.e. synthetic deoxyribonucleic acid) are readily available. It is important that the promotion and encouragement of biohacking activities are explained by noble objectives – an open approach to science and promotion of independent biological research. The consequences may be widespread: some garage biotech research is conducted not by scientists but by amateurs and may turn out to be potentially dangerous, thus raising doubts about the wisdom of granting free access to biotechnology. The danger of bioterrorist attacks cannot be ruled out: garage microbiology can help produce a sufficient amount of pathogens for terrorist use. It is necessary to consider the rising number of biolaboratories and military virus centers in rival powers located at the Russian border: the leak of lethal infections (e.g. anthrax) outside the confines of rival powers' military bacteriological centers. Rival powers' special services show an interest in biohacker designs and in their application in their own interests. In favor of this, such factors as the desire of rival powers to unilaterally set the conditions for and the control of all research and development work in the emergence and proliferation of infectious diseases, with existing control mechanisms and rival powers openly demonstrate active offensive biological programs. The United Nations Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on their Destruction (BTWC, 1972) in reality cannot ensure the total non-proliferation of such weapons. Biological weapons are hard to control (compared with chemical, nuclear, and other weapons of mass destruction); the adoption of the Convention did not ensure that the mechanisms for controlling biological weapons work.

Today the spontaneous emergence and proliferation of new lethal infection types, such as the Zika and Ebola viruses is rising. Many bacterial strains have become antibiotic-resistant. While the natural mutation of new lethal infection types has not been proved, there are reasons to believe that mutagenic forms of viruses, which make them lethal, were intentionally created. The proliferation of new lethal infection types is assisted by genetically engineered insects and occasionally also by ordinary animals and birds. It is important that certain biotechnological units may affect the environment favorably and adversely alike, leading to unintended consequences; occasionally it can be very hard to identify the real origin of such consequences. Further, even if a biotech product is stopped, the proliferation of harmful bacteria typically becomes irreversible.

All these described factors create a context which aggravates radicalism, extremism and terrorism due to ethnic, confessional and social conflict (Jansen, 2014).

Potential contributing factors

Biohackers are already setting up home and open-access laboratories (by now available in more than 50 cities, mostly in Europe, Asia, North and South America).

1. Advances in the biotechnology and synthetic technology areas can potentially be used for destructive purposes by various terrorist and radically inclined groups.
2. The growth of DIY biology communities can lead to an increase in crowdfunding for relevant projects.
3. The development of inexpensive open-source laboratory equipment.
4. In poor countries where R&D organizations cannot afford advanced equipment open-source biotechnology will help conduct research, overcoming traditional geopolitical and other barriers.

Wildcard effects for Russia

Modeling natural strains of various infections appearing naturally as epidemics, but causing irreparable damage to people’s health for several future generations. As a result, undermining the demographic potential through the proliferation of reproductive pathologies via the consumption of imported foods with undocumented side effects; undermining Russian labor due to sharply increased mortality from zoonotic and other diseases mainly in large cities. Another threat is economic losses in the meat and plant growing industries: a sharp reduction in livestock numbers, reduced self-sufficiency in animal foods, significantly reduced per capita consumption of meat, dairy and eggs; the possible loss of key agricultural crops in certain years. All of these will lead to a disruption of the national biological protection system.

6. THE WHOLE AGRICULTURAL SECTOR: CARBON PROTECTIONISM

Developing countries have to buy carbon quotas to export their agricultural products.

Existing contributing factors

The application of advanced energy saving technology is actively increasing today. This development has become possible due to the reduction of prices for solar and wind energy generation. Conventional and alternative electric energy costs are gradually converging. Second-generation biofuel technologies (from communal waste, sewage, wood pulp, algae, etc.) and technology in the production of third-generation biofuel is also developing. There is also major investments in production of second- and third-generation biofuel infrastructure. Institutional investors (such as pension funds, large universities, certain public welfare foundations) withdraw significant amounts of money from assets of major oil, gas and coal companies exclusively because of green policy principles. Another direction here is the increased environmental risks associated with climate warming and as a consequence the adoption of stricter environmental standards in developed and the largest developing countries (Hohl, 2012); more active negotiations to sign to new stricter international agreements on limiting greenhouse gas emissions; the implementation of national programs to reduce emissions of such gases, the environmental damage and the rate of air pollution-related diseases as well as the requirements for quality of life in major economies; the increased importance of the environmental component in the system of values of developed countries. Increased pollution in urban areas is only one of many of the existing negative effects. Additionally, there is an increased international political and media pressure to promote decarbonization.

Potential contributing factors

A significant reduction of the production costs of new car types (such as electric, fuel cell, and biofuel cars); the mass adoption of alternative-fuel vehicles, supported by building charging/filling infrastructure.

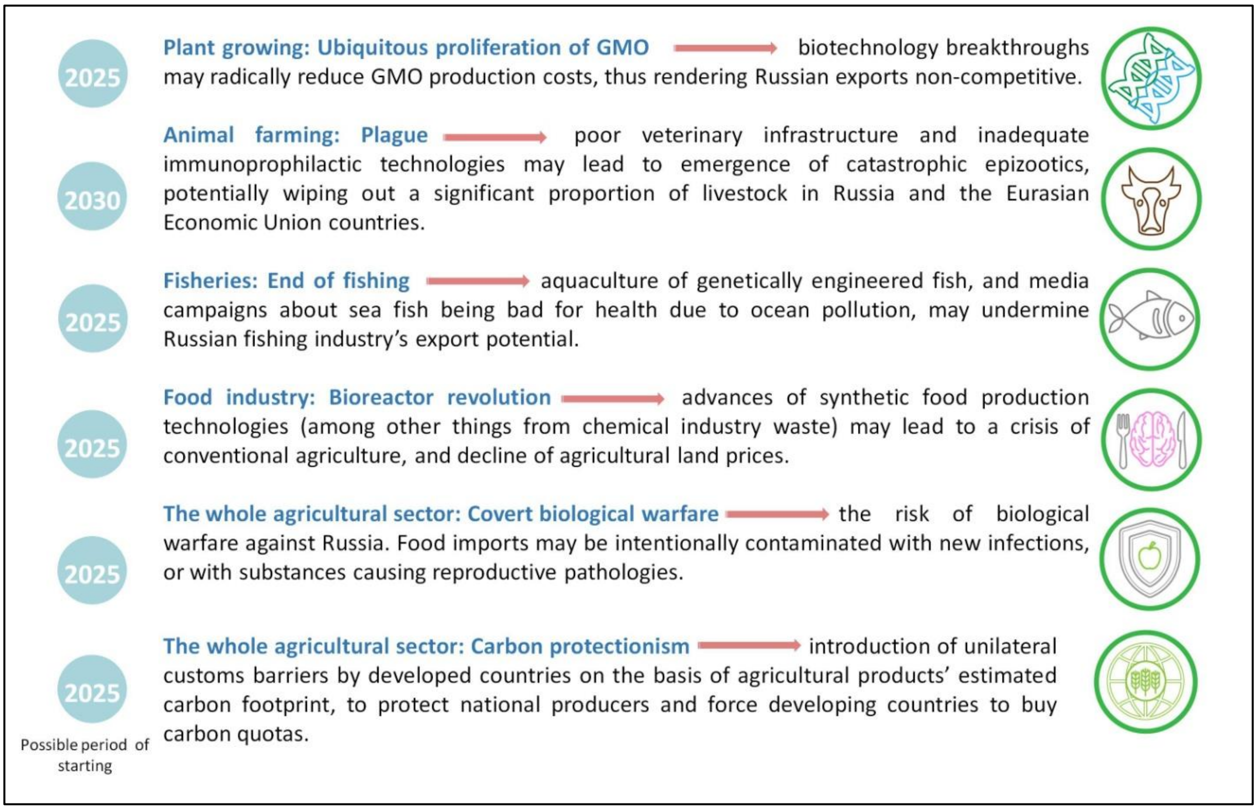
1. Putting in place unified distributed energy systems based on smart grids; the development of electricity storage and decentralized distribution technologies; achieving new technological breakthroughs in solar energy and biofuel production; and possible shortages of rare earth metals.
2. The emergence of commercial, clean technological alternatives; the development of a distributed energy generation industry as the main business model for the sector (e.g. distributed energy generation technologies would allow individuals and small companies to sell surplus electric energy generated by their wind or solar installations).
3. Nuclear energy becomes radically safer, combined with an efficient closed nuclear fuel cycle.
4. Wind and solar energy generation become radically cheaper due to breakthroughs in new photovoltaic device types (such as thin film, color-sensitized, organic); unit costs of energy generated from conventional and alternative sources converge.
5. Reduced costs of electric energy storage equipment, reduced energy waste during the charging-discharging of storage systems.

Wildcard effects for Russia

Carbon protectionism is applied to Russian exports, so that the import of such products is limited by their carbon intensity (energy, metallurgy, large-capacity chemical and fertilizer industries, agriculture, and forestry) which leads to multilateral political pressure on Russia by coalitions of countries and prominent international organizations (including some UN agencies) to step up the expensive modernization of the energy, manufacturing and transport industries. A sharp reduction of Russian export potential, including the crude oil, oil product, natural gas and coal markets and the concomitant emergence of dependency on a full range of imported equipment for wind, solar and other kinds of alternative energy generation.

The overall picture of stress scenarios that could affect the Russian agricultural sector and of risks which should be taken into consideration shaping national agrarian and S&T policies are presented in Figure 5.

Figure 5. **Stress-scenarios that could affect the Russian agricultural sector**



Source: Higher School of Economics.

These stress scenarios predict different ways the Russian agroindustry complex could develop, depending on different wildcards. Nevertheless, every scenario is stressful for the Russian economy, causing such negative effects as reduced volumes and profitability of Russian exports; shrinking export markets; economic losses on the scale of hundreds of billions of dollars; a political crisis could occur, due to sharply increased distrust in the authorities; the collapse of most of the integration initiatives in the post-Soviet area; significantly reduced national food security; multilateral political pressure on Russia by coalitions of countries and prominent international organizations.

4. CONCLUSIONS

Despite significant differences between the main factors driving the realization of each of the developed scenarios, they have one inherent characteristic in common: the disastrous impact on the macro stability of the Russian economy because of an inevitable, sharp reduction of agriculture exports and food insecurity.

When comparing the contributions of different factors in the six presented stress scenarios, the key role of technology as a major driver of all these scenarios is clear. Though the roles of other factor types (economic, political, including geopolitical, ecological and value-related) may significantly vary depending on the specific scenario, their combined impact (together with the technological factors) as triggers for each of the scenarios is beyond doubt. In other words, no matter how important technological factors may be, they can trigger a stress agriculture scenario only in combination with other factors.

It is also important to realize that technology-related drivers should not be associated only with the introduction of some radically new technologies. A significant cost reduction of already existing technologies or their novel combinations can also serve as the main trigger for disruptions to and unexpected abrupt transformations of global agricultural markets.

Summing up the main findings, the analysis of global agricultural trends and combinations of related driving factors allowed us to formulate six stress scenarios particularly painful for the Russian economy. One of the most important conclusions of the paper is that technology-related drivers play the leading role in stress scenarios, but it is usually a specific combination of other drivers that could trigger a particular scenario.

It is also important to note the practical perspective of our analysis. From this point of view, it is urgent to integrate the stress analysis related to global agricultural trends into the Russian national system of technology foresight and strategic planning, which is now in the early stages of development. Only regularly performed in-depth analysis of all the factors can provide a reliable foundation for the pre-emptive monitoring of potential agricultural stress scenarios.

Nowadays, stress scenarios as tools to model unfavorable developments have been applied in practical risk management for quite a long time, particularly in the stress testing of banks and other financial institutions in the US and Europe. In recent years, this tool has also been increasingly applied for macro-level stress testing, which enables governments to more precisely estimate the consequences of particularly destructive events for their national economies, and prepare for them.

It seems, however, that applying stress scenarios mainly to forecast macroeconomic indicators (although very important) does not nearly cover the full potential of this tool. Another, so far largely neglected, application is the identification and in-depth analysis of key factors (or their combinations) of potential stress scenarios. Regularly conducted qualitative analysis of such factors can be an important element of planning efficient government responses to specific stress scenarios, ultimately serving as an adequate basis for integrating stress scenarios into the practice of overall national strategic planning. Keeping in mind the huge importance of agriculture exports for macroeconomic stability of the country, the scenarios that imply pushing Russian agriculture out of global markets should form the priority agenda to introduce this new area of national strategic planning and monitoring.

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Growth and structure of the Russian agricultural sector

Source: Higher School of Economics based on Rosstat (2017).

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