Long-term Socioeconomic Challenges for Russia and Demand for New Technology

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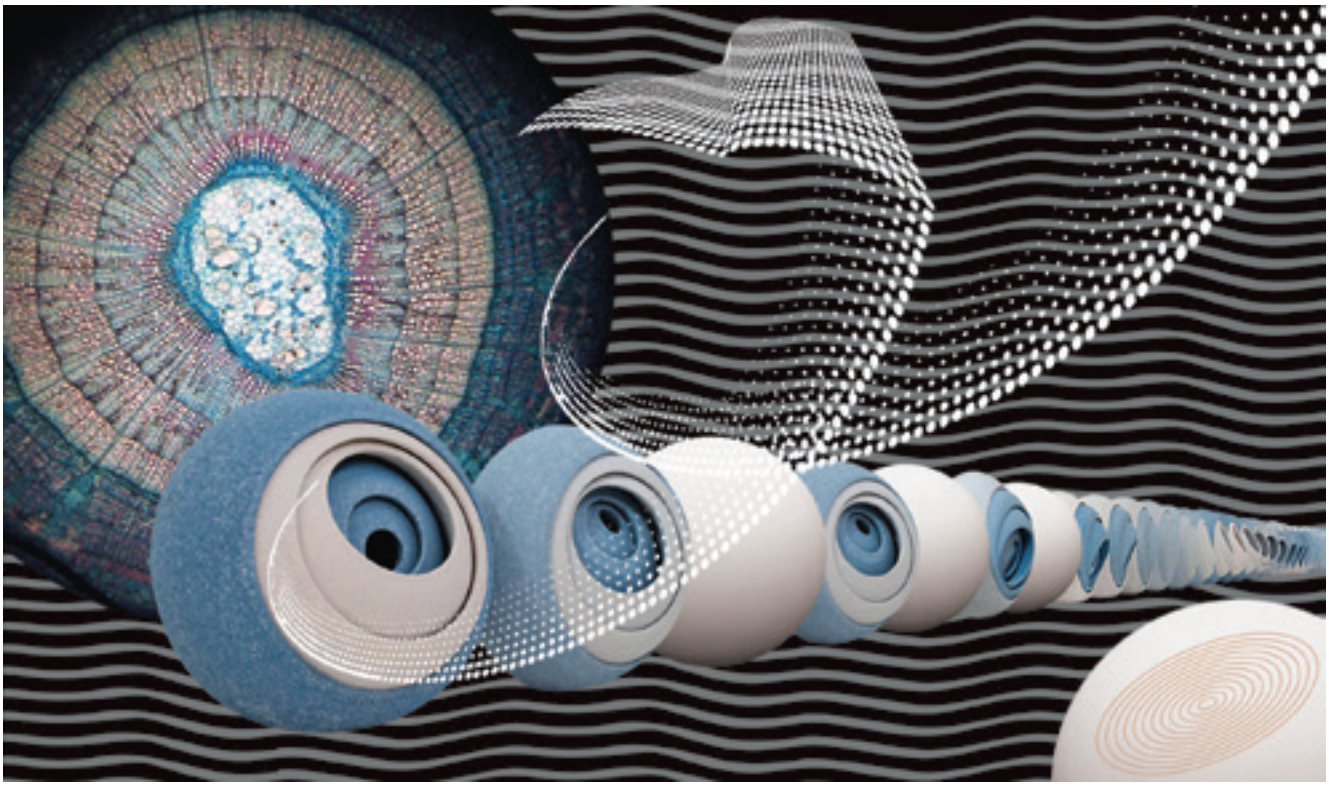

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Abstract

The primary long-term socio-economic challenges facing Russia – both global and country-specific in nature — drive demand for a range of technologies. We explore several groups of challenges, namely urbanization, demographic, socio-economic, the consequences of ageing, geopolitical, restricted access to key technological competences, climate change and its ecological consequences, as well as technological challenges largely associated with risks in ICT and biotech development, and the emergence of so-called 'killer technologies' that induce structural transformation in the economy.

We identify four groups of key factors influencing demand for new technology. First, those factors that strengthening Russia's role as a provider of key natural resources for the global economy. Second, of equal importance are those factors that support import substitution of various products of the global market, including electronic components, chemicals, and food products. Third, developing centres of technological competences plays a significant role, especially in export-oriented, manufacturing, and services sectors. These include nuclear energy, software, weapons and military equipment, military aircraft, and energy machinery. Finally, technological advancement would occur by integrating Russia within global technological value chains with external system integrators in pharmaceuticals, machine-building, petroleum products, and some ICT sub-sectors.

Keywords: long-term socioeconomic challenges; demand for technology; technological development; S&T policy

DOI: 10.17323/1995-459X.2015.4.6.17

Citation: Apokin A., Belousov D., Salnikov V., Frolov I. (2015) Long-term Socioeconomic Challenges for Russia and Demand for New Technology. *Foresight and STI Governance*, vol. 9, no 4, pp. 6–17. DOI: 10.17323/1995-459x.2015.4.6.17

Defining the factors that shape demand for technological innovations is the most important aspect of developing a long-term socio-economic development strategy on any level or scale. To solve this problem recent research proposes a variety of instruments [*Granger*, 1980; *Molnar*, 2010] involving textual analysis [*Gokhberg et al.*, 2014] and expert surveys as part of the Foresight studies [*Landeta*, 2007; *Popper*, 2008]. The methodology used for this research paper has been described in detail in *Belousov et al.* [2012]. We consider technological development as the primary solution to the long-term challenges facing Russian socio-economic development. Therefore, when analyzing demand for innovation, it is important to define the nature of specific challenges by projecting global dynamics onto the domestic situation. We have opted for the most topical and widespread groups of challenges in academic writing: demographic, urbanization, geopolitical, climate and technological. Comparing these with the development conditions of the domestic economy will allow us to identify industry challenges and opportunities.

Long-term socio-economic development challenges are in many ways shaped by the global context, i.e. global trends. However, a number of specific features of the current state of the Russian economy play no small role in determining Russia's course. Among others, the work [*Gokhberg et al.*, 2014] is devoted to an in-depth analysis of the characteristics of global-level factors. Based on the results of this study and other research, we will carry out our own evaluation of some of the most important trends, risks to global development, and opportunities for Russia. It will analyze the industry-specific features of technological challenges.

The methodology used was developed as part of the preparation and update of the coordinated long-term socio-economic and science and technology (S&T) development forecast for Russia [*Abramova et al.*, 2013; *Gokhberg*, 2014]. This was carried out by the Centre for Macro-economic Analysis and Short-term Forecasting (CMASF) in collaboration with the Institute for Statistical Studies and the Economics of Knowledge (ISSEK) at NRU HSE.

Main global challenges to long-term socio-economic development

Russia's socio-economic development challenges are directly dependent on long-term global trends, where such global trends are largely unaffected by the state of the domestic economy. In the period up to 2030, we can expect the following global socio-economic and S&T challenges to persist:

- waning population growth;
- intensification of international conflicts;
- worsening environmental and climate problems, which would also be linked to the supply of resources for growth;
- new risks connected to technological development, primarily linked to bio- and information and communication technologies (ICT).

Waning population growth

A key factor in the growth of developing countries over the coming decades will be the second demographic transition, accompanied by a fall in mortality resulting from modernized health care, improved nourishment and better public health conditions. In these societies, the persistently high (albeit gradually falling) birth rate is combined with rapidly decreasing mortality, especially among babies and children. As the birth rate drops as a result of urbanization, the spread of consumer culture and other modernizing tendencies, the demographic situation in developing countries will start to approach that of developed countries, characterized by low, near-zero population growth [UN, 2012]. It goes without saying that this is a projected trend, one which we can hardly expect to take root fully before the middle of this century.

An important, although not decisive in terms of its effects, global demographic factor might be the renunciation of the 'one family, one child' policy in China with the possible transition to a policy directed towards stimulating growth in the birth rate. At the same time, the next wave of the country's industrialization, in particular its urbanization, will likely bring about a fall in the birth rate to less than two children per woman of reproductive age.

The continued waning population growth will give rise to two groups of effects. The first group of effects are reflected in the majority of forecasts (for example, in the World Population Prospects forecasts published by the UN [UN, 2012]) that

include the urbanization process, an ageing population, and the continual and possible increase in migration processes.

In less developed countries, urbanization goes hand in hand with the process of industrialization and, more widely, the modernization of society and economy. Urbanization processes will intensify further primarily in states undergoing industrialization (China and others), where a group of post-industrial global centers (such as Shanghai) emerge as modern technological and financial metropolises alongside growth in traditional industrial cities.

Ageing populations is a steady trend for developed countries and a comparatively new one for developing countries. While the population of developing countries continues to be relatively young (due to high mortality and a current gradual decline in mortality), in future their age structure will become comparable with that in developed countries.

Migration trends are characterized by a degree of uncertainty in the long-term. Today, migration trends are largely supported by the demographic imbalance between developed (labor-deficient and wealthy with ageing population) and developing (labor-abundant and poor with young population) nations. Technological changes in the labor market, especially in terms of automation, can significantly alter the situation. It would seem that the challenges brought about by this trend have the greatest long-term impact.

The less obvious effects of the second group resulting from migration from developing to developed countries relate to the growing importance of technologies intended to address the deficient nature of pension systems and poor access to 'long-term money' for the elderly; spread of new forms of education, transition to 'urbanist' consumption; and the spill-over of social, international, and interfaith conflicts.

The development of technologies intended for the elderly is primarily attributable to the spread of specific illnesses that require long-term treatment among this age group. According to data from [*Alemayehu, Warner*, 2004], roughly half of all expenditure on medicine by US residents are incurred after the age of 65, and roughly one third after the age of 85. This includes biomedicine, ICT and transport for the elderly and disabled, and on the educational, financial and other infrastructure geared towards them [*Peine et al.*, 2015]. Current policy in the field mentioned above significantly undervalues the market outlook of global ageing and the inevitable transition to a socio-material constitution of later life.

Growth in the elderly population creates shortcomings in pension, and more broadly, financial systems, making it harder to access 'long-term money'.[1] The shift in the balance between the proportion of employed and those incapable of work in the economy will lead to a reduction in savings rates in developing countries (e.g. in the Pacific Rim, Russia, and a number of Arab states). This shift occurs irrespective of effective pension system in these countries or the dependence of essential support services for the elderly on voluntary savings and intergeneration transfers. In turn, this wreaks havoc on the ability of such economies to finance deficits (and therefore overconsumption) in developed countries. Another possible effect is a general tension in the venture funding market for high-risk innovation projects.

The falling demand for unqualified labor globally is leading to guaranteed economic competitiveness, not through a demographic or emigrational inflow, but rather through the continuous modernization of existing human capital. This increases the importance of lifelong learning and technology-oriented education in general. Simultaneously, in developing countries we are seeing a transition to 'urbanist' consumption with demand for high-quality food products (in particular, for beef in China and in Arab states), environmentally-friendly produce (predominantly in the West) and for clean water[2]. The electrification of consumption alongside the overall trend of increasing energy efficiency is contributing to intensive growth in the consumption of electricity and a fall in demand for hydrocarbon energy sources, especially oil products.[3]

[1] On average, in OECD countries [OECD, 2013a] the work force retires from the labor market when it reaches the official pension age. In Asian countries (South Korea, Japan, etc.) people actually take their pension 5–10 years after the legal age, and in Latin American countries (Mexico, Chile, etc.) — 3-5 years after. Cultural and regional idiosyncrasies in developing countries with regard to retirement tend to prevail over economic factors.

[2] This poses a challenge for a large number of Russian industries, especially agriculture, as the lag in water management technologies is reaching a critical level. Of course, in many developing countries, in particular in China, the problem of water pollution is even less favorable.

[3] Rapid development is expected in non-hydrocarbon (electrical) energy technologies (nuclear, solar, wind, etc.). We can expect to see intensive research and development (R&D) in thermonuclear energy, which is likely to be rolled out commercially after 2030.

Intensifying international conflict

This trend can be caused by new centers of economic, and consequently, technological strength coming into direct competition with one another, combined with a crisis in existing international institutions that follow a monocentric model. The growing migration from developing countries in recent decades is already leading to the spillover of social, international, and interfaith conflicts into developed countries.

This trend, and not simply its military and political aspect, is discussed extensively in the literature [National Intelligence Council, 2013]. The financial and economic side of the problem, also defined as global imbalances, causes structural risks in relationships between developed debtor countries and developing creditor countries [*Mendoza et al.*, 2009]. Despite the fact that the last five years have halted successfully the intensification of these imbalances, the disparity continues to have an impact on the global economy. An explanation for this phenomenon has not yet been offered in the academic literature.

Realization of environmental and climate problems, including linked to the supply of resources for growth

A general trend in recent years has been the growing demand for environmentally friendly products as well as an environment shaped partially by progress in urbanization on a global scale. As a result, there is the intensifying specialization of regions globally, including in identifying land for global environmental/resource reserves and, partly, the excessive environmental load in a number of developing countries, including in the Pacific Rim. The deficit of a number of vitally important resources such as clean drinking water and fertile land is increasing amid ground water pollution, soil erosion, and landscape degradation, which have all been significant factors behind the deteriorating quality of life in China and other developing countries.

By the early 2030s, the question of adapting to long-term and very long-term processes, including climate change, will be firmly rooted on the global political and technological agenda. Among other things this means global warming[4] irrespective of the causes (man-made or long-term natural factors), and changes in the power, water salinity, temperature and other characteristics of major oceanic flows (El Niño, the Gulfstream), similar atmosphere processes, and rising ocean levels.

One trend that is observable clearly and is linked directly to those outlined above is the rising prices for natural resources, especially hydrocarbons, uranium, and certain types of metal. Although there is no physical shortage of some of these resources, the extraction methods are growing increasingly complicated and expensive, in particular for shale gas, oil sands, and hard-to-extract heavy, viscous oils dispersed through metal deposits. The technological landscape of the next decade [*Gokhberg et al.*, 2014] suggests that price formation in the energy market will be dependent on the following situation. We will either witness a consistent increase in prices for conventional hydrocarbons, or an intensive transition to new forms of energy capable of significantly cutting down oil prices in the market (at least in the second half of the forecast period).

Risks connected with technological development

Technological development gives rise to a separate group of risks, especially the rapid obsolescence of existing technology and the increasing complexity of new solutions and platforms. At the same time, these risks open up opportunities in niche areas, which can supplement existing technologies.

The exponential development of information and communication technologies as a 'super factor'; the information society, economy, and science

Long-term and intensive development in ICT is attributable to the accumulated inertia of technological development and large-scale investment in this field. The unique feature of ICT is its total penetration into all areas of social life, including

[4] 'Current climate change in Russia should on the whole be characterized as persistent warming at a rate exceeding the rate of global warming by more than two and a half times. According to observation data, the average rate of warming on the Earth's surface was 0.17°C/10 years for 1976-2012, while in Russia it is warming at a rate of 0.43°C/10 years. The most rapid warming is seen in the northern latitudes. 2013 was very warm: sixth among the warmest years since instrumental observations began in 1886. The average temperature for the year in Russia was 1.52°C above 1961-1990 norms, while the average global temperature for 2013 only exceeded the norm by 0.50°C. However, the trend of slowing warming, witnessed globally since the start of the 21st century, has not yet been detected on Russian territory' [HydroMetCentre Russia, 2014].

the production of goods and services, which results in an uneven impact on developing and developed economies. While developing economies have the chance to gradually strengthen their position on the global technological map, which includes developing the production of electronic components, software, and content, developed economies face the prospect of reindustrializing and maintaining their technological leadership through personalization and customization of goods and services, including traditional manufacturing [OECD, 2013b].

Alongside the general characteristics of ICT noted above, a clear trend in this sphere is the growing role of the software component in the added value of end products. The bulk of the profit is now generated not by the manufacturers of components and hardware (processors, electronics, etc.), but by owners of the intellectual property which shapes the unique properties of the finished article. This fundamentally changes the structure of the ICT market, which would shape its dynamics in the medium-term until the emergence of radically new processor manufacturing technologies [WEF, INSEAD, 2014].

This field is characterized by a high risk of 'failure' of an ordinary surge in development with the revolutionary and extremely intensive; while the evolutionary trajectory is as a result of insufficient investment or the existence of fundamental technical or scientific problems (quantum effects, etc.). Such a reduction in growth results from reduced R&D in energy. Some of this research, linked to making use of quantum effects, is dependent on the development dynamics of new ICT, while at other times research serves as a prerequisite for opportunities to arise such as in the case of adaptive power grids. Moreover, a slowdown in the development of a number of closely related technological fields is inevitable:

- biomedicines, where studies, in particular genomics and proteomics, use cutting-edge ICT;
- new materials — nanotechnologies, composites, biocompatible polymers;
- new energy — nuclear and thermonuclear synthesis, adaptive energy systems, nanophotonics, etc.

A failure in the development of new ICT drastically increases the likelihood of a general cooling of S&T development [Ernst & Young, 2014].

Biomedical technologies as the core of the new technological lifestyle

The technological base of the new mode of life will, according to forecasts, form over the next 15 years right up to the 2030s, which will witness the rise of biomedicine as a key and promising area of economic development. Developments in genetic diagnostics and therapy, artificial organs and tissues, treatment biosynthesis, and cell therapy hold great potential during this phase. Cross-disciplinary fields such as bioinformatics and new areas of bioengineering will give a new impulse to development [DHHS, 2014].

One of the most important medico-technological fields in scientific research is pharmacogenetics, which is the study of the relationship between disease, genes, proteins, and pharmaceutical drugs. A new area has in fact arisen in medicine: the development of targeted treatments based on genome mapping results [DHHS, 2013].

In the main, the risks associated with technological development give rise to the following long-term effects and trends:

- saving resources — energy, water, certain types of metals — this trend will peak by 2030, by accelerating efforts to reduce the man-made load on our natural environment and developing closed production cycle technologies; more importance will be paid to establishing and adhering to environmental standards — these will become an important factor allowing access to markets, primarily in developed countries;
- increasing price volatility for natural resources as a result of simultaneous growth in the cost of extraction and tighter regulations regarding the efficiency of energy technologies used;
- the growing intensity of existing and new migration flows, caused by the exhaustion of natural resources / deterioration of the environmental situation; the spread of conflicts over resources in developing countries (for access to water, fertile soil, etc.)

Key challenges facing the long-term development of the Russian economy

The long-term challenges and risks for the Russian economy and society can be broken down into several groups, which only partly reflect global trends. In the

period up to 2010, we can expect challenges to emerge or intensify in such socio-economic areas as:

- demography;
- secondary urbanization;
- ecology: risks of ecosystem deterioration;
- supply of resources: growth in the cost of extracting minerals amid stabilizing global hydrocarbon prices;
- technological development: 'closing' technologies and new de facto standards;
- social stability: new conflicts and intensifying inequality;
- geopolitics: conflict and access to key technological expertise.

Demographic challenges

Like other industrially developed countries, Russia is facing the problem of an ageing population and the end of the second demographic transition. Birth rates came close to less than two children per woman of reproductive age while mortality among the working population (including non-medical reasons such as work or transport-related trauma, violent causes, etc.) also dropped. The contribution of these factors to the increase in life expectancy maybe traced to progress in medicine. As a result, the number and share of elderly people among the Russian population is steadily growing. Thus, by 2030 the level of demographic burden (the number of elderly citizens per 1,000 citizens capable of work) will grow from the current 400 to 510 (Figure 1).

The demographic dynamics described give rise to the following economic and financial risks:

- a reduction in budgetary stability as a result of the increase in pension liabilities, demographic burden ratio, and health care spending;
- an imbalance in the financial system when savings rates fall and the pension and social budgetary burden rises due to changes in the demographic burden ratio;
- social tension caused by a mass influx of migrants amid a shortage in labor resources: growing conflict within and between different ethno-social groups, growing state spending on rehabilitation of migrants, etc.;
- conservation of excess labor intensity in certain sectors of the economy (residential construction, trade, etc.), resulting in lowered standards in comparison to developed economies.

Challenges of secondary urbanization

The post-industrial stage of economic and social development is characterized by the concentration of the population in megalopolises, especially in so-called global cities (such as Moscow and St. Petersburg in Russia) in a close network. This type of agglomeration allows for a higher standard of living and offers fundamentally different opportunities for self-fulfillment in areas of human capital development, choice of career path, lifestyle, etc., when compared with average-sized cities.

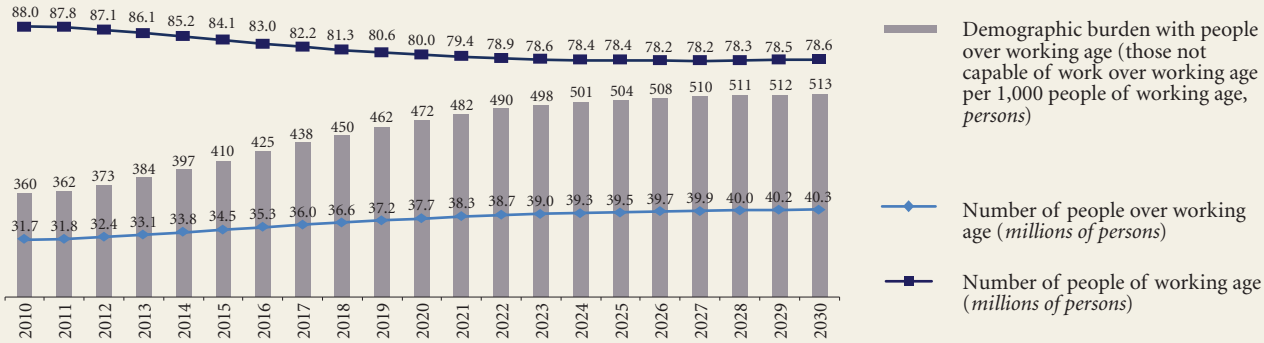
The risks of secondary urbanization are linked to the degradation of human capital in average-sized cities and the emergence of 'backwardness zones' as a result of the outflow of qualified specialists. A more direct structural economic risk lies in the fact that the crisis in average-sized cities could bring about substantial losses for a number of traditional industries located in them — car manufacturers, for example.

Risks of deterioration of the natural environment

Russian territory has suffered significant pollution from industrial waste and transport emissions, especially in old industrial regions and areas of metal or chemical production. According to data from Rosgidromet, the Russian Hydrometeorology and Environmental Monitoring Agency, in 123 Russian cities, in which 52% of the urban population reside, the level of air pollution is classified as high or very high. These cities are primarily old industrial cities with older technology of manufacturing which is harmful to the environment (e.g. in Yekaterinburg, Volgograd, Arkhangelsk, or Ufa). A lot of the present day's mass production cause environmental pollution, which is characteristic of regions with high concentrations of industrial capacity (e.g. Norilsk, Magnitogorsk, Cherepovets, Kyzyl, Kurgan, Nizhny Tagil, Chita, and Salekhard).

In view of the growing public demand for a decent quality of life, intense pollution of the environment could become an additional factor contributing to

Fig. 1. **Demographic burden dynamics in Russia**



Source: compiled by the authors based on Rosstat demographic forecast data, average variant.
Available at: http://www.gks.ru/free_doc/new_site/population/demo/progn1.htm, accessed 25.01.2015.

the outflow of population from industrial regions. As a result of deteriorating environmental conditions, especially in the Pacific Rim countries and, perhaps, Central Asia, Russia faces the threat of uncontrolled immigration.

Resource challenges: growth in production costs and the stabilization of global hydrocarbon prices

As new tight mineral extraction regions open up and the industry re-orients itself towards new forms of hydrocarbons, the cost of extraction in Russia will steadily rise. Oil and gas production in Russia is already one of the most expensive in the world and is showing further signs of cost pressures (Figures 2, 3).

Combined with the highly likely stabilization of dollar prices for hydrocarbons because of technological re-equipment of production companies, growth in the cost of extracting Russian oil and gas will pose a high risk of crisis in the industry, caused by a shortage of financial resources among the major players. In any event, we should not expect a surplus of funds in future. In contrast to the mid-1990s, the sector has once again started to meet the growing demand for financial resources thanks to other industries.

This in turn poses macroeconomic risks of losing budgetary stability and disruption of the balance of payments, as they are highly dependent on commodity exports. At the same time, the inflow of direct foreign investment, loans, and lending is also determined to a degree by the state of the oil and gas markets. The limited opportunities to manage and redistribute oil and gas revenue are fraught with systemic crises for the domestic economy.

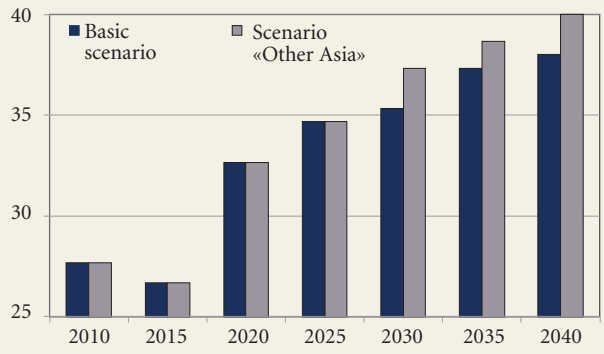
Technological challenges: 'closing' technologies and new de facto standards

Current technologies have the potential to radically change the industry structure of the Russian economy either by fully liquidating ('closing down') certain markets or creating barriers to Russian products penetrating into developed countries, i.e. replacing it with low-profit and/or high-risk emerging markets. Five areas of technological development can be identified which have the potential to bring about significant risks in certain sectors (industries): ICT, personalized medicine, technologies allowing bespoke production of mass-market products, new energy, automated vehicles, and armaments. A more detailed typology of these technologies and the associated risks is given in Table 1.

The greatest risks from this perspective come from the following technological areas:

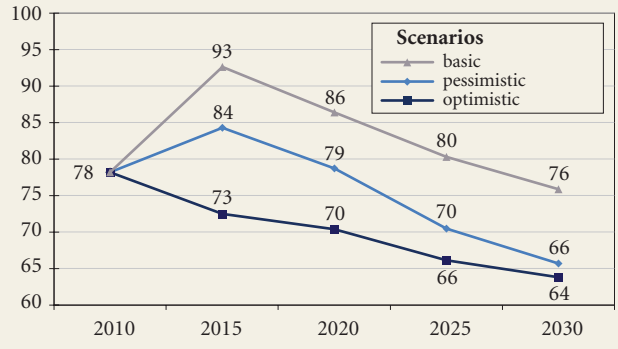
- ICT (including modern electronic components, the transition to new principles in physics, etc.), including their combination with cognitive technologies, which involves ousting 'traditional', and therefore obsolete, ICT products and associated medium-tech goods and services from the production market, and the defense and general engineering industries, and forming new de facto standards;
- personalized medicine radically transforming the pharmacology and medical services market on a scale comparable with the emergence of antibiotics or mass remote monitoring practices;

Fig. 2. **Capital-output ratio of the Russian fuel and energy sector in 2010** (*dollars/t.o.e.*)



Source: Russian Energy Agency.

Fig. 3. **Global Urals crude oil price dynamics in 2010** (*dollars per barrel*)



Source: CMASF.

- advanced 3D printing, which makes it possible to produce heterogeneous articles, in terms of their density, thickness, and other characteristics, and automated production of mass bespoke products (for example, using RFID assembly methods). These technologies place significant pressure on the automotive and other traditional industries (especially those with high labor costs) and contribute to reshoring, i.e. the reverse transfer of production from developing to developed countries, thereby further complicating the potential competition conditions for Russian companies;
- new energy, energy saving technologies, batteries, and adaptive energy system management technologies are capable of removing domestic hydrocarbons from the market, which involve high production costs. On the other hand — and even more importantly — the development and spread of super batteries and adaptive energy technologies will allow us to reduce the amplitude of day-to-day fluctuations in energy demand and supply in the general economy by reducing peak loads, which could be an additional factor in the reduction of demand for Russian energy products;

Table 1. **Relationship between new technologies and the forms of activity 'closing them down'**

New technology	'Closing' technologies or activities
Modeling of human intellect, cognitive consciousness and behaviour models	A broad spectrum of standardized analysis and forecasting in business (including financial markets), meteorology, medicine (even as far as an individual digital doctor), education ('distance student'), military, etc.
Evolution of the Internet: semantic web, Internet of Things	Revolution in intellectual activities (semantic web), new de factor consumer standards, possibly investment (Internet of Things) and military products
Radical transformation in the ICT market as a result of changes in electronic component base production technology (the end of Moore's Law, the development of new materials, photonics, etc.), the creation of breakthrough quantum technologies.	Obsolescence and 'closing down' of traditional ICT, replacement of de facto standards in associated fields
Transition to personalized 'health medicine', radical increase in life expectancy, control of human cognitive abilities	Crisis in traditional mass medicine, differentiation of 'old' health care for the poor and 'new' for the well-to-do, break-up of previous business models geared towards mass production of drugs
Stricter environmental standards and safety standards for production, transport, food products, consumer goods, buildings and structures, waste; customization of consumption	New de facto standards closing markets to traditional goods
Advanced 3D printing technology	Crisis in labor-intensive medium-tech automotive and metal manufacturing industries; emergence of new business models in high-tech sectors (including the high-quality expansion of outsourcing, in part through small and medium companies); reverse transfer of manufacturing into developed countries as a result of the leveling out of costs
Development of new energy, battery systems and energy network management systems	Gradual move away from the use of more costly hydrocarbons in favor of alternative energy sources; rise in car energy efficiency; trend of rapid expansion of the electric and hybrid car market
Development of automated transport and armaments	Ousting of standardized equipment and services from the market (for example, in rail transport); shrinking of regular military technology and armaments markets
Development of flexible automated production allowing for customized mass production output	Domestic crisis in traditional labor-intensive industries; automated automotive industry, possibly, production of mass consumer electronic and electrical goods; increased opportunities to transfer production

Source: compiled by the authors.

- automated transport and armaments preconceiving new de facto standards and involving the liquidation ('closing down') of a number of significant Russian manufacturers in market niches (railway engineering, military aircraft engineering, etc.).

Social challenges: conflicts and new inequalities

The development of personalized medicine, the radical increase in life expectancy, the control of cognitive abilities, and the improvement of 'brain-computer' interfacing technologies signify a fundamental increase in the abilities of individuals. In Russian terms, however, this growth is inevitably uneven due to the significant social inequality that reflects the income structure of the economy: in recent years, the income ratio has fluctuated between 16 and 17.

At the same time, the continuing socio-economic imbalance and consolidation of the class structure in society will cause a significant deterioration in the situation. However, the necessary tools to overcome this situation are currently lacking.

Geopolitical challenges: the struggle for access to key technological expertise

A number of global development scenarios make assumptions about the intensification of international conflicts, which could make it more difficult for domestic companies to access key technological expertise in economics and security, as was the case in 2014. This turn of events in particular presupposes significant growth in the scale of the problems facing the Russian S&T complex.

Industry specifics of challenges to long-term socio-economic development

Industry analysis allows us to outline the current challenges to the development of certain sectors of the Russian economy that are already experiencing certain weaknesses (Fig. 4).

First, *we can expect a steady decline in the global situation*: according to most existing assessments, in future, commodity prices will remain relatively low and are unlikely to rise significantly above the 2015 levels. Another negative factor is the growing cost and falling accessibility of technologies and funding. Both of these factors are responsible for the low value of the national currency since 2015.

Second, *we should expect a negative impact on business income from the increasing cost of basic resources and factors of production.* This problem, to a certain degree, confronts all industries. A comparably new, but no less dangerous factor may be

Fig. 4. **Reality of risks and threats to key industries in the real sector of the Russian economy**

	Global risks	Fall in income	Deficit of labour resources	Lack of access to credit	Backwardness of technology	Loss of skills	Closing of markets
Agriculture							
Extraction and processing of hydrocarbons							
Extraction of other minerals							
Food manufacturing							
Fruit and vegetable production							
Timber industry							
Chemical industry							
Engineering industry							
Power industry							
Construction							
Transport							
Communications (ICT)							
Trade							

Degree of urgency minimal low medium high maximum

Source: compiled by the authors..

the sharp fall in incomes in the oil industry due to growing capital expenditure and limited access to modern technologies amid the stabilization or even fall of global hydrocarbon prices. In turn, this causes problems in a wide range of associated industries such as the oil refining, chemical industry, engineering, and so on.

Third, *the deficit in labor resources is forecast to intensify*, especially qualified labor, which will further increase workforce costs. This risk is caused by a combination of negative demographic trends and the lack of specialists with a specific profile, attributable to the shrinking incomes of a number of manufacturing companies. As a result, the major players refrain from bringing in qualified and highly paid personnel or break the 'breeding' cycle for specialists at the companies themselves.

While in the early 2000s, the situation in the labor market was in part successfully mitigated by attracting specialists from post-Soviet countries (engineers and qualified workers — from Ukraine and Belarus, partly — from Transcaucasia, low-qualified workers — from other former Soviet republics), today this resource has been virtually exhausted, in part due to the reorientation of the migration flows towards EU countries. Labor-intensive industries such as engineering, construction and the service sector, find themselves in a particularly vulnerable position.

Fourth, in view of the nature of the policy conducted by the Bank of Russia, *access to credit resources for non-financial companies is expected to remain difficult*. Price uncertainty and reduced income in the global commodity markets are forcing players in the banking and financial sector to revise their risks upwards, which means that corporate lending is more expensive.

Fifth, *the backwardness of the technological equipment at production facilities will grow*. In the post-crisis period, there was clear trend of fading investment activity despite the relatively favorable overall climate in 2010–2012 and positive consumer dynamics. The worsening of the situation, combined with the increased risks in 2013–2014, further weakened the incentives for long-term capital investment and thereby suppressed technological development in the domestic economy and increased the dependence of key sectors of the economy on other countries.

Sixth, *a skills crisis as a result of a change in traditional business models* is starting to develop. In recent years, a number of high-tech industries (for example, aircraft engineering — the *Sukhoi Superjet*) have developed the 'high-tech designer' model, involving global outsourcing of virtually all, including key skills, excluding systems integration. With the active expansion of exports (and the conformity of the foreign currency structure of sales to the spending structure), this model is highly dependent on the strength of cooperation with external partners. While the formation of networks of global 'power centers' will in fact be accompanied by more conflicts, critical skills in high-tech industries will require far stricter control than today.

Seventh, *a liquidation of markets (especially in developed countries) is taking place due to changes in de facto standards and the introduction of 'closing' technologies.* This challenge, posed by changes in technological and environmental standards, could affect virtually all industries and forms of production. It poses the greatest threat to the pharmaceutical and medical industry, power engineering, construction materials production, and the production of a broad range of engineered consumer, investment, and defense products.

The challenges and risks described bring to the fore an additional administrative problem: the reduced effectiveness of existing (resource-intensive) state support instruments for technological development such as special federal and state programs. The majority of R&D funding provided by these programs is geared towards high-tech industries — aerospace, nuclear, defense — and the resources themselves are concentrated in central coordinating organizations and are issued to support technological development through existing business models. At the same time, the evolution of production technologies is accompanied by the emergence of new business models with the redistribution of the influence across the whole chain of centers of excellence.

At present, traditional high-tech engineering industries are facing these very problems. However, the most indicative example is the space industry. Thus, in the USA private space technology manufacturers such as SpaceX (which manufactures the Falcon 9 rocket and Dragon freight capsule), Virgin Galactic, or Boeing are actively increasing their share of the industry, not only for satellites, but rockets and freighters that intend, among other things, to put astronauts into orbit. Private companies offer far lower prices for orbital services than traditional state players, thanks largely to optimized production chains. The globalization of this model allows for efficient savings through outsourcing and poses a threat to the

competitiveness of domestic producers with a high level of vertical integration and relative cost of rockets. The situation in the Russian space industry is being intensified by the transition to a new technology platform – the 'Angara' family is due to replace the 'Soyuz' series, the foundations for which were laid back in the 1950s, which helped to maintain low costs.

In the future, the transition to new business models may also be initiated in other high-tech industries in which Russian players would retain some degree of competitiveness.

Conclusion

An analysis of the challenges facing Russia's socio-economic development has allowed us to make several important conclusions relating to technological modernization and long-term national development strategy.

The Russian economy is set to face two waves of strategic challenges in the near future, which would demand market flexibility and adaptability. The first wave (in roughly 2020 or slightly later) will likely be linked to the end of economic growth as part of the 'energy pole' model. We cannot be certain today as to which of the new technologies in the fields of energy, energy saving (super batteries), adaptive networks, unconventional forms of hydrocarbons, and so on, will come to define the global agenda. There can be almost no doubt that the energy markets may undergo a drastic and irreversible transformation within the next 5–10 years. For Russia, the situation is complicated further by the growing capital intensity of energy resource extraction at newly developed and old sites.

Another factor is the possible revolution in de facto standards linked to the development of all-pervading ICT (the Internet of Things) and new materials. Those companies which have not subscribed to the new standards will likely find themselves ousted from the market. The expanding demographic and environmental crises and increased security risks will serve as the general backdrop for this.

The second wave (roughly 2030–2035) is expected to be linked to fundamental changes in medico-biological technologies and in ICT. The corresponding shifts are capable of causing large-scale negative social effects — the emergence and intensification of new social inequalities, such as asymmetry in access to pharmacological and genome technologies to control human abilities. Combined with the formation of a global educational and cultural network and the increased security risks, this could undermine the stability of the social structure in Russia and its sovereignty.

Global and internal Russian challenges will affect different industries to differing degrees. However, all industries, even the most low-tech, will exhibit persistent demand for modernization. In the case of basic industrial sectors, modernization is capable of encouraging the development of a whole range of medium- and high-tech chain-based production; for example, the extraction and initial processing of raw materials — oil and gas engineering, transportation of raw materials — transport engineering, etc.

From an import substitution perspective, a small group of industries in three sectors hold the greatest potential:

- electronic components, medical technology, machine tool and engine engineering, oil and gas engineering, ship building, agricultural equipment and forestry;
- chemical complex — extraction of rare metals, production of composite materials, dyes and varnishes, plastics, cleaning and polishing products, articles made from resins and plastics, pharmaceuticals;
- food industry — production of meat and fish products, preserved fruits and vegetables.

Long-term growth opportunities are linked largely to the development of existing strong centers of excellence, including those in foreign markets. In industries such as software development, nuclear energy, and partly the production of armaments, military technology, aircraft, energy equipment, certain classes of lorries, and so on, Russia is capable of acting as a technology donor and center of excellence on a global scale. For pharmaceuticals, engineering, motor fuel production, and certain types of ICT, a rational strategy is perhaps getting embedded in global production chains, including through outsourcing with external systems integration (importing skills)

The development of new technological skills is vitally necessary to maintain Russia's national competitiveness and security. Such a task, however, requires

a relatively strict prioritization of efforts in this sphere in the absence of adequate financial (various forms of revenue) and human resources in simultaneous 'frontal' modernization.

Acknowledgements

The article was prepared within support from RF Ministry of Education and Science in the framework of the research project «Scenario analysis of the long-term impact of Russia's S&T development in a macroeconomic context" (Grant Agreement no 02.603.21.0003, unique identification number RFMEFI60314X0003). The used data are retrieved within studies conducted in 2015 in the framework of the NRU HSE Basic Research Programme.

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