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Problems of Industrial Digitalisation in Russia¹

The paper examines Industry 4.0, which is a world-leading concept of industrial development, involving the use of a wide range of advanced digital technologies and total automation of production. From a methodological perspective, the author considers digitalisation of production in three aspects: application of digital technologies in traditional industry; rapid development of the digital sector of the economy; emergence of new opportunities for human development. Adopting such an approach the research systematises technological changes and economic models critical to the industrial development. By performing a bibliographical search the author outlines the modern concepts of digital production development. The paper carries out an assessment of economy digitalisation in Russia and its regions on the basis of statistical and information materials published domestically and internationally. The author identifies the risks for the domestic industry, associated with its probable lag in technological development, and proposes potential ways to neutralise them.

JEL classification: O33, O38

Keywords: Industry 4.0; digitalisation; industry; digital economy; technological development.

Introduction

The main global industrial development concept is a phenomenon called Industry 4.0 to which the terms “industrial Internet of things” and “digital production” are directly related. Industry 4.0 involves end-to-end digitalisation of technological and business processes and their comprehensive integration into digital ecosystem. There are a number of interrelated, not yet well-established concepts: “digitalisation”, “digital economy”, and “digital production”. Despite the fact that in the initial understanding, digitalisation means replacement of analog data collection and processing systems with digital ones, in the modern sense, it refers to application of a wide range of advanced digital technologies (computers, networks, and software) and total automation of production and business processes in the economy, as well as mass application of digital technologies in the social sphere. Integrity of the phenomena known as the digital economy and importance of global trends for domestic industry necessitate a search for new scientific approaches to assess and systematize digitalisation, to manage risks and threats, and to develop measures for their mitigation. The abovementioned ideas predetermined the objectives and tasks of this study.

Research methodology

From our perspective, digitalisation of productions manifests itself in three important trends: application of digital technologies in legacy industries; rapid growth of industries and companies associated with the production of software, electronic components, data storage, processing, and transmission, e-commerce, creation of web services; the emergence of new opportunities for human development, including knowledge sharing, occupational skills training, etc.

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In this context, we will discuss the manifestations of digital economy in three main aspects (Fig. 1):

- Creation and development of new industries, primarily in the information and communication technologies sector of the economy.
- Modernisation of the existing production facilities by adopting digital technologies.
- Development of digital services for personal and social advancement.

Fig. 1. Systematisation of digital economy manifestations

Some researchers believe digitalisation is a stage in the IT development as part of the sixth wave of innovation [1; 3; 4]. In this case, development of information services is part of an infrastructure specific for the emerging wave, and the leading companies in the digital economy can form a core of it. Rating of the world's largest companies in their industries can serve as one of confirmations of this approach. The largest companies today are involved in ICT, while 50 years ago they were mainly machine-building and energy firms. When studying the digital economy development, we tried to apply the above approach of assessing its manifestations in the three spheres.

Digital economy concepts

Digital technology development processes and prospects of their industrial application were first presented in 2011 in Germany as part of the government concept "Industry 4.0...". This event is regarded as a starting point for the development and application of such concepts by the leading nations of the globe including the Internet of Things, Industrial Internet (USA), Industry Value Chain Initiative (Japan), Industrial Innovation 3.0 (South Korea), Productivity 4.0 (Taiwan), Smart Factory (Netherlands), Usine du Futur (France), High Value Manufacturing Catapult (Great Britain), and Fabbrica del Futuro (Italy).

In Russia, both the government and the business community monitored these processes and formally responded in 2017 by developing the State Program named "Digital Economy of the Russian Federation". Regional programs are also being prepared locally (for example, the Planning Office of the Government of the Sverdlovsk Region is setting up a regional program on digital economy).

Such concepts usually contain goals and schedule for modernisation of the existing production facilities by employing new digital technologies, establishment and development of ICT enterprises, and creation of an appropriate infrastructure and legal framework in the country. Apart from the Program "Digital Economy of the Russian Federation", a number

of strategic documents that have been adopted in Russia have a significant effect on application of digital technologies in the Russian economy:

- Strategy of scientific and technological development of the Russian Federation;
- Strategy of IT industry development in the Russian Federation for 2014–2020 and projected up to 2025;
- The State Program of the Russian Federation “Information Society (2011–2020)”;
- National security strategy of the Russian Federation.
- Open Government projects (portals: electronic budget, public e-services, open data, etc.) are being implemented, electronic registration and trade platforms (third-party only insurance, medicines, prescriptions, register of apartment rental patents, etc.) have been created, road maps have been formed for the National technological initiative – Healthnet, Neuronet, Aeronet, and Marinet, which determine the lines of technological development.

Lines of development and key technologies of digital economy

Prerequisites to digital revolution, as already noted, include rapid development of existing and emergence of a number of new technologies with the key ones being: growth of information networks – population and enterprise coverage reaches 90% or higher; production equipment and personal devices connected to global networks; remote computing power and storage facilities options; emergence of programs, computing resources and sensors capable of collecting and analyzing huge amounts of data. Products become more sophisticated and include not only mechanical, but also essential electrical and electronic components, and more recently software, the “weight” of the latter keeps growing. Apart from these technologies, it is worthwhile to mention robotisation, artificial intelligence, virtual reality, geolocation, etc., which are also associated with digitalisation.

For the industry, the most important technologies in this sphere are 3D-printing, robotisation, artificial intelligence, Internet of things and connectivity of facilities, automated engineering, new sensors and transmitters, and application of intelligent networks in power industry. In general, these technologies allow the cyber-physical systems – i.e. facilities where devices operate without human intervention and are controlled by software through advanced sensors – to be set up and employed in the industry. The evidence of this is total automation of production and business processes, and maximum horizontal and vertical integration of information. Moreover, such facilities can be distributed among countries and managed as a single package via the Internet.

Technological development within the concept of digital economy implies a reorientation of various engineering and technological systems, which would affect both the high-tech sector of the economy and conventional industries. Transition to a new model of economic development involves both the transformation of industrial development institutions and business models, and improvement of industrial policy. Technologies, organisational features, and economic effects associated with digital economy are summarized in Table 1.

The Industry 4.0 technologies and their possible impact on the industry, as well as their applications in production, have been described in a variety of publications, for instance in [13; 15].

Digital production

Technological changes have made it possible to create and apply a number of scientific and practical concepts that allow modern digital technologies to be comprehensively implemented in industrial production. Bibliographic search helped identify a number of approaches including Intelligent Manufacturing [17], Cybermanufacturing [9], Distributed Manufacturing Systems [12; 14], Cloud manufacturing [10], Cloud-based design and manufacturing for service-oriented products [16], IoT-enabled manufacturing [7], Hybrid Manufacturing Cloud [11],

Table 1

Technologies, organizational features, and economic effects of economy digitalization

	Information and communication technologies sector	Conventional industries	Society
Technologies	Big data. Internet of things. Cloud computing. Artificial Intelligence. Virtual reality applications. Connectivity of facilities and people via the Internet. Geolocation	Big data. Additive technologies and atomic precision manufacturing. Automation and robotization. Internet of things. Computer-aided engineering. Cloud computing. New sensors and transmitters. Low- and post-carbon energy. Utilization of intelligent networks and distributed generation. Connectivity of facilities	Smart mobile devices. Broadband Internet connection. Augmented reality. E-commerce. Personalized advertising. Different types of 3D simulations. Geolocation technologies, geolocation marketing. Blockchain. Digital services to monitor home, movement, health condition, etc.
Organization	End-to-end automation of business processes, application of ERP, CRM, PLM. Digital platforms. Knowledge sharing. Lean production	Distributed cyber-physical systems. Industrial networks. Distributed generation. End-to-end automation, application of ERP, CRM, PLM. Digital platforms. Establishment of service-oriented business architecture	Disappearance of jobs, the emergence of new occupations. Distance learning, knowledge sharing. Public e-services. Growth in non-cash financial payments. Development of telemedicine
Economy	Achievement of high levels of complexity in information products and services. Reduction of the time required to manufacture and market goods. Growth in productivity. Increase in the number of new products	Increase of manageability of production and technological processes. Reduction of costs and time consumption	Automated pricing. Product sharing. Personalized production and consumption

etc. Moreover, the number of academic papers on the subject in the global research databases has been steadily growing for more than 25 years.

Formation of a digital ecosystem for the industry, namely *new digital platforms*, is an important feature of digitalisation. Typically, these include:

- technological design – networks, data centers, cloud technologies, data processing and data submission applications;
- new business models, ecosystems of developers and suppliers of individual modules and applications formed around a platform company;

• new principles of interaction between producers and consumers, an open, publicly accessible infrastructure for interaction.

According to the Center for Strategic Research Foundation [5], in 2015 there were 64 platform companies in China, 63 in the US, and 9 in the UK, while Russia accounted for only three companies classed as platform.

In the sphere of *social* development, we are primarily speaking about the emergence of network technologies and various types of networked devices that allow a remote, real-time acquisition, processing, and transmission of significant amounts of data. These technologies made it possible to implement a number of services that have significantly changed the life of society. In regard to the problem of increase of human capital for the purposes of industrial development, the following new technological capabilities can be identified:

- customisation of products and services produced by the industry at client's request;
- digital services for real-time monitoring of home, movement, health, etc.
- a new quality of education, remote services (for example, about 18 million students are signed up for the Coursera online educational platform), switching from project-oriented to experiment-oriented education;
- feasibility of conducting research based on "big data", artificial intelligence, and digitalisation;
- development of "4P" medicine (preventive, prognostic, patient-oriented, personified);
- growth in non-cash financial payments;
- public e-services and computer-aided control of legally binding actions.

It should also be noted that the change in the labour market structure towards robotisation (according to some sources, up to 25–30% of jobs will be displaced in the near future), disappearance of a number of "obsolete" occupations and demand for the new ones associated with the use of advanced production technologies, intellectualisation, robotisation of production, stronger creative component of labour, etc.

The integrated approach allowed the author to summarize the features of industrial digitalisation with regard to the drivers and structural principles of production systems (Fig. 2).

Fig. 2. Drivers, principles, and outcomes of industrial digitalisation

A thorough literature review suggests how the adoption of digital technologies would occur in the main sectors of domestic industry. For the extractive industries, the most promising directions are automation, robotisation and personnel cuts, digitalisation of extraction, with growth in business models based on supply of digital services and assets (e.g. cloud technologies), 3D modeling of deposits, radar monitoring systems, Mine of the Future [6] and Digital Mine [8] concepts. Processing industries, as part of transition to product platforms and the need to manage the entire life cycle of a product, will use big data analysis, artificial intelligence, and new digital modeling methods. At the production stage, "smart" factories, additive production, atomically precise manufacturing, and advanced materials will be created.

Production of metallic materials for additive manufacturing, materials with targeted properties will be highly relevant in metallurgy. In the energy sector there is a tendency towards system disintegration, transition to so-called smart networks, scaling up the renewable energy sources, distributed generation, control automation, application of energy storage technologies, security protection, and expansion of energy applications. As a consequence of technological development there will be a change in business models and formation of flexible markets with a demand management capability. Industrial infrastructure will also undergo significant changes including, in particular, the emergence of intelligent transport and autonomous vehicles, high-speed communications, data storage facilities and much more. Similar changes should also occur in financial activities, security, education, and healthcare.

It is important to create new industries oriented to cultivating industrial consumption markets, including those for fundamentally new branches of economy. Critical technological directions for these industries will involve the use of equipment and materials for the post-carbon energy; new materials; microelectronics and new generation element base; biotechnology and production of medical equipment; new sensors, transmitters, and measuring instruments, etc.

Assessment of the actual state of Russia's economy digitalisation

A number of indicators are used to assess the digital economy state in the Russian Federation and its regions. Traditionally, Rosstat, the Russian Federal State Statistics Service, determines the share of organisations that use computers, information networks, conventional and specific software. Indicators used to assess the regions characterize the population's involvement into using networks, high bandwidth networks coverage, online services for purchases, etc.

These statistics were generally studied in the author's previous research and indicated that Russia's industry does not yet demonstrate the ability to follow the global trends in this area. The quality of renewal of production indicates that existing technological structure and organisational solutions in the industry are reproduced with a low level of innovation and corresponding labour productivity. Application of modern information technologies demonstrates moderately positive dynamics, especially in the sphere of human services. In the industry, there has been an increase in the use of software products to computerize a wide range of economic tasks and, in particular, specialist software. The specialist software range employed by the industry predetermines the use of global databases, computerized interaction with partners, but does not provide for extensive use of design and process control tools (Fig. 3).

Fig. 3. Shares of organisations using different types of specialist software, %

In the sphere of human resourcing, Russia’s industry does not demonstrate an increased need for specialists in automation, IT, and communications. At the same time, judging by the estimated number of university graduates in these spheres up to 2020, an increase in demand for them in the economy is expected (Fig. 4).

Fig. 4. Estimated number of specialists graduated from Russia’s higher educational institutions by job clusters, people

By most of the indices that assess countries’ information society advancement, development of information services and digitalisation, Russia usually occupies 30th or 40th places. For example, according to the ICT development index for 2017 (<https://www.itu.int>), Russia ranked 45th. This is also confirmed by research published domestically. For instance, according to the compilation by the Institute for Statistical Studies and the Economics of Knowledge (ISSEK), a branch of the National Research University “Higher School of Economics” (NRU HSE), Russia generally holds 30–40th places in the world [2].

As for the degrees of digital economy development in the regions of the Russian Federation, among the leaders should be named Moscow and St. Petersburg, the republic of Tatarstan, Moscow oblast. Regions of the Urals and Siberia (Chelyabinsk, Sverdlovsk, Novosibirsk, Tyumen oblasts, and Khanty-Mansi autonomous okrug) have good positions but play in the second league (Table 2).

Table 2

Leading regions by the development of digital economy
(rank in the Russian Federation) [2]

Region	ICT employment	Broadband Internet subscribers (per 100 people)	Mobile Internet users (per 100 people)	Share of organisations using broadband Internet	Share of organisations using cloud services	Share of households using broadband Internet	Share of households using the Internet	Share of population making purchases online	Share of population using public e-services
Moscow	1	2	1	2	1	7	5	4	6
Saint Petersburg	2	3	12	3	10	2	2	13	33
Tatarstan	3	6	25	28	13	7	9	17	1
Sverdlovsk oblast	6	8	65	8	13	20	19	28	50
Tyumen oblast	9	72	82	19	28	9	7	7	5
Chelyabinsk oblast	12	8	80	19	20	26	19	32	20
Novosibirsk oblast	4	1	50	65	35	32	40	55	29

Table 2 (concluded)

Region	ICT employment	Broadband Internet subscribers (per 100 people)	Mobile Internet users (per 100 people)	Share of organisations using broadband Internet	Share of organisations using cloud services	Share of households using broadband Internet	Share of households using the Internet	Share of population making purchases online	Share of population using public e-services
Khanty-Mansi autonomous okrug	17	17	35	14	13	3	2	4	2
Nizhny Novgorod oblast	4	6	45	14	28	53	72	59	33
Moscow oblast	7	65	1	14	13	20	11	28	42
Kaluga oblast	47	13	25	28	20	74	72	76	3

Risks of industrial digitalisation in Russia

The trends presented in the paper pose a number of risks for the Russian economy.

First, it is its critical dependence on technologies, equipment, and software products of foreign origin. According to the Russia's Ministry of Industry and Trade, dependence on imports in the automotive, shipbuilding sector, in agricultural, oil and gas, and heavy engineering industries exceeds 50%. And as for the pharmaceutical, medical, radio electronic, and machine-tool industries, it is beyond 70%. This risk should be reduced by stimulating and creating conditions for the emergence of domestic proprietary designs, as well as by diversifying suppliers of technology and equipment.

Second, there is a growing threat that the Russia's industry will drastically lag behind in terms of labour productivity, resource efficiency, and time required to develop a new product, which leads to a risk of weakening the country's positions on the new and even the traditional markets. As a result of intensive technological progression of the leading countries, the Russian Federation may fall out of the global production chains in high-tech industries.

Third, dramatic changes in the employment structure and freed-up labour may occur as a result of computer-aided manufacturing and changes in the structure of economy (structural shift from energy and metal industries to those of information and communication technologies, engineering). In this regard, the risks associated with the Russia's low ability to convert a high level of human capital development and research insights into technological innovations should be taken into account.

Conclusion

In order to neutralize the risks and ensure that the Russian industry evolves in accordance with the current trends, an effective system should be built for managing the modernisation of the national economy in the context of a clear orientation toward catching a new wave of innovation.

Important directions include timely regulatory changes to secure the processes of technological and industrial modernisation. It is necessary to modernize the system for managing scientific and technological development to ensure an increase in the share of R&D expenditures in GDP, and to improve scientific and technological performance. To increase the innovative potential of the industry, it is critical to develop an industrial and information infrastructure capable of providing secure access to global networks, knowledge sharing, development of IT companies at the international level and their participation in leading digital platforms and ecosystems.

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Проблемы цифровизации промышленности в Российской Федерации¹

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Статья посвящена исследованию наиболее актуальной в мире концепции развития промышленности, называемой «Индустрия 4.0», с которой связаны применение широкого спектра новейших цифровых технологий и тотальная автоматизация производства. Методологически цифровизация промышленного производства рассматривается в трех сферах: применение цифровых технологий в традиционной промышленности; стремительное развитие «цифрового» сектора экономики; появление новых возможностей развития человеческого потенциала. В рамках этого подхода нами систематизированы технологические изменения и экономические модели, важные для развития промышленности. Библиографический поиск позволил выделить современные концепции развития цифрового производства. Проведена оценка цифровизации экономики в Российской Федерации и регионах на основе отечественных и иностранных статистических и информационных материалов. Определены риски для отечественной промышленности, связанные с ее отставанием от технологического уровня развитых стран, а также возможные подходы к их нейтрализации.

Ключевые слова: Индустрия 4.0; цифровизация; промышленность; цифровая экономика; технологическое развитие.

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