Digital Transformation and Current Trends in the Technological Development of the Industrial Complex: Russian Experience

Olga Smirnova and Lyudmila Chesnyukova

Abstract Digital transformation (Industry 4.0) is characterized by the large-scale coupling of technologies in industrial production, high operating activities based on cyber-physical systems, and the introduction of digital technologies in business processes, which have already proven their effectiveness in world practice. The study aims to assess structural changes in the industrial complex of Russia in the digital economy. New technologies used in industry are identified as a result of the study based on the concept of Industry 4.0. The analysis of the introduction dynamics of digital technologies in the industrial complex of Russia, which involves the intensification of innovative long-term development, is carried out. The authors present a theoretical model of digitalization of the industrial complex, based on a set of interrelated components from the beginning of the digital design and modeling technology development to further production, through networks of industrial cooperation and subcontracting, including logistics, sales, and subsequent service of digital services, IT services, industrial things from the Internet.

Keywords Digital transformation · Industrial complex · Industry 4.0

1 Introduction

Currently, the development of the industrial complex in the context of digital transformation is determined by many technologies already available in the industrial market, such as cloud computing, advanced robotics, 3D printing, artificial intelligence, the Internet of Things (IoT), and big data analytics. All of these, in addition to the technological transformation in the industry, are giving way to new forms of value creation such as the "collaborative consumption economy" and new forms of

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V. Kumar et al. (eds.), *Digital Transformation in Industry*, Lecture Notes in Information Systems and Organisation 54, https://doi.org/10.1007/978-3-030-94617-3_14

networking such as inter-industry clusters, business networks, and virtual structures, which will emerge as these technologies come together, generating new products and services, new business models, new forms of labor activity. The widespread use of digital technologies, the development and implementation of new technologies, and technological innovations can positively impact the development of the industrial complex of Russia.

The Boston Consulting Group report defines the digital economy as all economic activity based on digital goods and services, whether new business models or transformed business models. The document discusses three dimensions of the digital economy: the impact on value creation of 9% direct impact, another 9% induced impact, and 1% additional externalities [9]. According to the Institute for Statistical Studies and Economics of Knowledge of the Higher School of Economics, the share of digital technology in the value-added of the business sector is 3.4%, while for OECD countries, it is 5.4% [17].

New joint research conducted by PwC and ABBYY shows that one of the threats faced by actors in the industrial complex in the implementation of digital technology is the lack of skills or resources to effectively manage modern technology [23]. These threats faced by industrial complex entities must be addressed through digital adaptation. Thus, in an increasingly flexible, connected, and technological marketplace, businesses will need to remain competitive and economically, socially, and environmentally sustainable.

The article aims to analyze the development of Russia's industrial complex under digital transformation, to highlight promising areas of industrial complex development from the perspective of modern technology based on the implementation of tools of Industry 4.0 in industrial production.

2 Literature Review

The modern development of the industrial complex is impossible to imagine without the widespread introduction and use of information and digital technologies. Studies on the adaptation and implementation of digital tools in the real economy confirm that in the global perspective, the future of the industrial complex depends on the implementation of advanced digital technologies in the business environment [13, 18]. New technological solutions provoke the transformation of existing business processes (inter-industry clusters, business networks, and virtual structures), society, and the economy, affecting value chains, production, and trade.

The issues of digital and technological transformation of the industrial complex are considered in the works by Romanova [2, 24], Pozmogov [22], Tolkachev [32] from the position of using digital technologies in the business environment to extract additional income and competitive advantages. The main trends of digital transformation in real economy organizations are reflected in the works by Alcácer [3], Bauernhansl [6], Cheng [10], Filippov [11], Landro [18], Morrar [21], Tapscott [31], who considered digitalization as an implementation of Industry 4.0 tools.

Economists Frank, Mendes, Ayala, Ghezzi consider the digital transformation (Industry 4.0) in terms of stimulating technology, considering the increase in the value of the production process and management systems in the production environment [12]. These approaches are considered complementary concepts. The scientific article by Sima, Gheorghe, Subić, Nancu aims to substantiate the relationship and the impact of Industry 4.0 on the development of human capital and consumer behavior [29]. A study by Androniceanu, Georgescu, Tvaronavičiene, Androniceanu identifies the impact of digitalization on labor productivity in many developed countries and industries [5]. Economists Gisario [14], Miśkiewicz and Wolniak [20] conclude that the introduction of digital technology in the industry leads to increased energy efficiency and is a competitive advantage. The articles by Glotko, Polyakova, Kuznetsova, et al. provide theoretical provisions, approaches, and principles of digitalization of state regulation in the field of industrial data and define the essence and forms of this regulation [15]. Guseva and Dmitrieva supplement these provisions by studying the relationship between digital technology and engineering solutions and justify the transition to new models based on information technology [16].

The research results presented in the works by Akberdina [1, 2], Bodrunov [7, 8], Gribanov [13], Sukharev [30] allowed the development of an applied toolkit for studying the digital transformation of Russia's industrial complex. The transition to digital platforms is a key tool for the digital transformation of the industrial complex; it forms a digital environment whose individual elements interact with each other.

3 Materials and Methods

Let us highlight the key technologies used in the industry based on Industry 4.0:— Artificial Intelligence (AI), the Internet of Things (IoT), blockchain (BC), and supply chain traceability. These technologies complement each other in industrial processes, playing specific roles in the industry digitalization (Industry 4.0): AI as a set of algorithms that improve business processes in industrial manufacturing; IoT allows the control and management of remote access, automated devices that improve efficiency in the industry; identification and electronic traceability system that allows greater data transparency from beginning to end in the supply chain and analyze the actions of IoT, improving efficiency in industrial manufacturing; the use of blockchain technology in industrial production, in the era of digital technology to function effectively in a business environment according to the criteria of multiple participants without the participation of third parties.

The use of the above technologies positively affects the efficiency of business models, production flexibility, and the level of service of the industrial complex. These digital technologies simultaneously create additional opportunities and threats associated with advanced information and digital technologies, providing outstripping industrial development.

The introduction of digital tools in industry will increase the efficiency of industrial production and increase the competitiveness and adaptability of business structures.

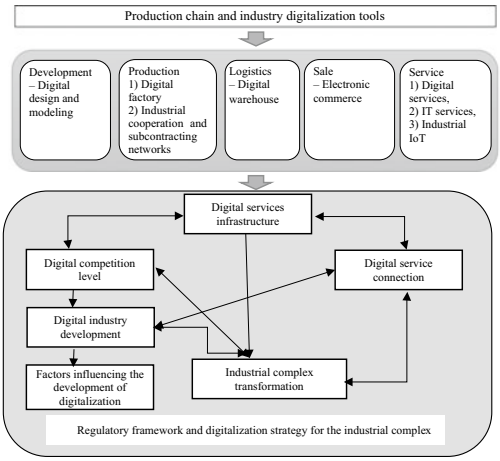

Fig. 1 The model of digitalization of the industrial complex of Russia

Figure 1 presents a theoretical model of digitalization of the industrial complex of Russia, including digital tools at various stages of the production chain. In addition, the model highlights the most relevant technological opportunities identified in the context of the transformation of the industrial complex in the transition to Industry 4.0.

The proposed model defines a systematic relationship between each chain component, placing it in a value network of suppliers and customers forming a digital ecosystem and digital platforms of the industrial complex providing a logistic architecture of production and product delivery industries of the industrial complex, and potentially brings a rapid adaptation of the company to market needs.

Analysis of the impact of digital technologies on the development of the industrial complex of Russia is an important strategic task. Currently, the Ministry of Digital Economy of Russia is developing the National Index of Digital Economy of Russia. The methodology for calculating the index is expected to be approved by the end of 2021. The index development is based on the world's leading practices and considers the country's peculiarities. The application of this methodology will make it possible to analyze the digitalization process of the industrial complex and create an appropriate assessment of the industries that form the Russian industrial complex [4].

A comprehensive methodology for technological development directions of the Russian industrial complex is based on primary Rosstat indicators for 2010–2020. The analysis includes the following indicators: (1) distribution of digital technologies in the industrial complex organizations that used personal computers, websites, local area networks, servers, and global information networks [1, 30]; (2) dynamics assessment of the use of new technologies and technological innovation in the industrial complex; (3) structure analysis of research and development costs for high-tech, medium-tech, and science-intensive types of economic activity. In addition, the structure of the industrial complex is assessed by indicators [1, 2, 30]: the share of mining

and manufacturing in Russia's GDP; analysis of the growth rate of labor productivity; the degree of depreciation of fixed production assets in Russia.

The proposed methodology of comprehensive analysis allows assessing the degree of digitalization of the industrial complex and identifying development opportunities associated with the introduction of technology in the organization of the industrial complex. Note that developing a digital access infrastructure is critical to provide individuals and businesses with access to digital content and services and enable operators in the supply chain (e.g., application and content providers) to interact with each other without third-party involvement.

4 Results and Discussion

The industrial complex is the defining sector of economic activity in Russia. Let us analyze the structure of the manufacturing and extractive industries according to Rosstat indicators for 2010–2020 (Figs. 2, 3 and 4). Industry occupies a key position in the GDP structure and forms more than 25% of Russia's gross domestic product (GDP) [26].

From 2010 to 2020, in general, there was a slight increase in the industry share in GDP; extractive industry—0.45%, manufacturing—0.53%, and high-tech and knowledge-intensive industries—2.03% (Fig. 2).

Active transition to the development and implementation of new technologies and technological innovations in the industry will increase labor productivity, which is determined by the ratio between the indicator of production volume (GDP) and the resource use indicator (Fig. 3) [1]. In the Russian economy as a whole, according to Rosstat, from 2010 to 2020, there was a slight increase in labor productivity—1.3% [28]. Based on the average growth rate in projected 2020, labor productivity was 101.2%, indicating a slight decline. There was also a slight increase over the entire period in manufacturing (3.6%) and mining (0.9%). In the forecast 2020,

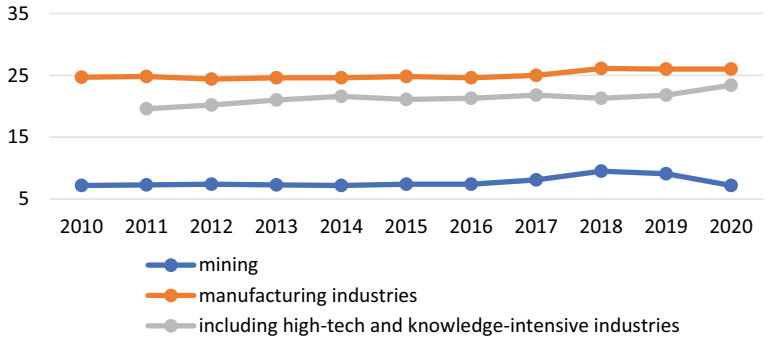

Fig. 2 The share of mining and manufacturing industries in Russia's GDP for 2010–2020 [26]

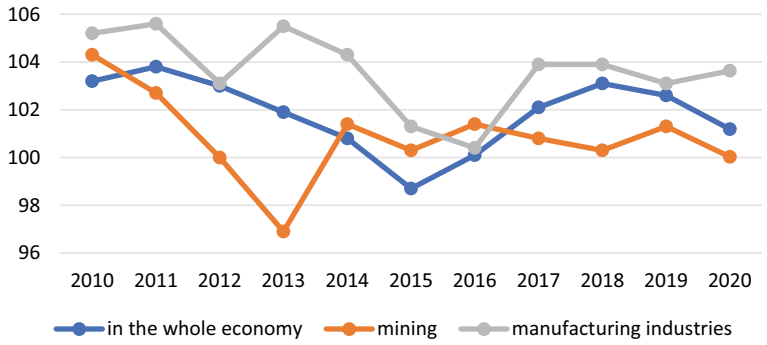

Fig. 3 Dynamics of labor productivity growth rates for 2010–2020, % [28]

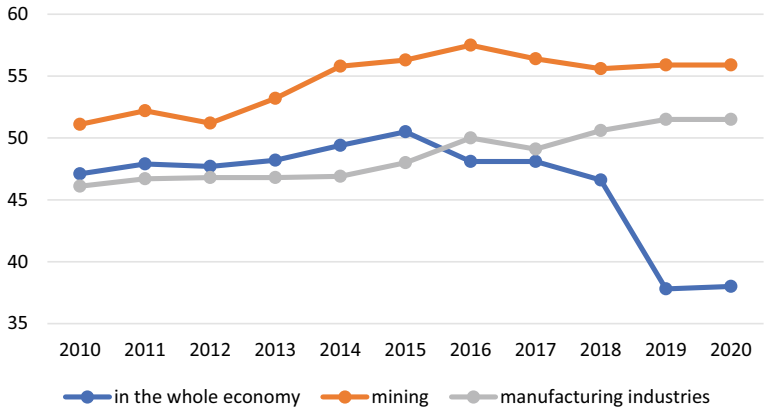

Fig. 4 Dynamics of the depreciation degree of fixed assets in Russia, % [28]

the growth rate of labor productivity in manufacturing was 3.6%, which indicates some positive dynamics. In turn, in the extractive industries, labor productivity, in general, will remain unchanged. This is due to the low level of manual labor and the predominance of mechanization and automation in industrial production.

Labor productivity in industry is influenced by various factors, including the degree of wear and tear of basic production assets of enterprises (Fig. 4).

For the analyzed period from 2010 to 2020, there is a decrease in the indicator by 1.9%, which indicates the renewal of equipment (Fig. 4) [28]. The wear of equipment is 1.1% and in the extractive industries 0.9%, which indicates a high degree of wear of equipment employed in the manufacturing and extractive industries for the whole period in the manufacturing industry. At the same time, industrial production is more capital-intensive than other sectors of the economy, and at present, the modernization and transformation of the industrial complex are proceeding at a slower pace.

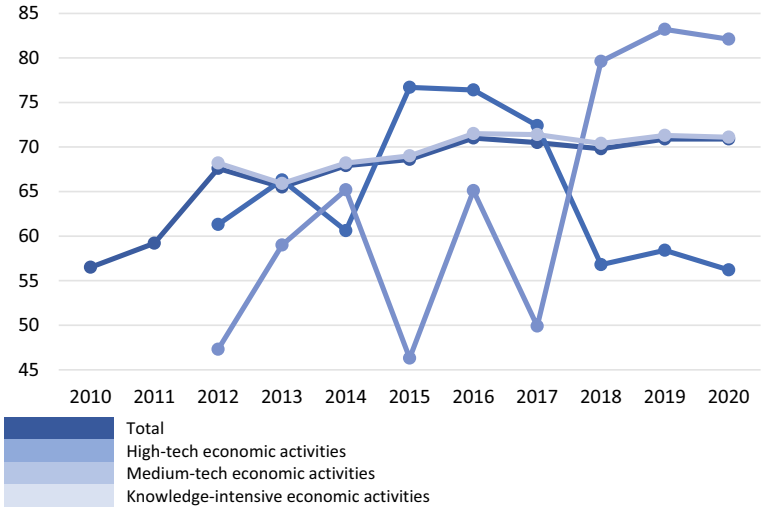

Fig. 5 Dynamics of the share of domestic expenditures on research and development in priority areas of science, technology, and engineering in the total volume of domestic expenditures on research and development in Russia, 2010–2020, % [27]

The development of digital technologies in industrial production involves the intensification of innovation. Let us consider the indicators of innovation activity (Fig. 5; Table 2). There is a slight increase in the volume indicator of innovative goods, works, and services by type of economic activity: mining—the growth was 2.60%; manufacturing—the growth was 1.46%, which indicates the positive dynamics [27].

Let us analyze the dynamics of the share of domestic expenditures on research and development in the priority directions of science, technology, and engineering development in 2010–2020; this indicator varies significantly depending on the type of economic activity (Fig. 5) [27]. In the knowledge-intensive types of economic activity for the entire analyzed period, there is a slight increase of 0.55%. In high-tech economic activities, there is a decrease of 0.25%. In medium-tech industries, which include manufacturing, an increase of 10.78% is noted.

As part of the study, let us highlight indicators of the use of digital technology in the industry in Russia, such as the use of organizations of local computing and global information networks of the industrial complex [1, 30], organizations' use of personal computers, servers, and websites. Let us assess the components of digital technology in the economy of Russia as a whole and highlight their impact on industrial development (Table 1).

According to Table 1, from 2010 to 2020, there was a decrease in the use of personal computers in the surveyed organizations for all types of activities by 1.4%. There is also a change for the worse in the extractive (−2.35%) and manufacturing (−1.52) industries. For the analysis of the share of organizations that used servers, a positive trend is noted in the economy as a whole; the increase is 12.15%. A pronounced positive trend is observed in manufacturing (13.75%). In the extractive

Table 1 Economic growth rates of indicators of the share of organizations that used personal computers, servers, websites, local computing, and global information networks, % [25, 27]

Type of activity	Indicator	2011/2010	2013/2012	2015/2014	2017/2016	2019/2018	2020/2019
Total	Personal computers	100.3	100.0	98.4	99.7	99.5	86.3
	Servers	108.2	104.2	179.3	99.6	100.7	86.2
	Organizations with a website	115.8	109.3	105.7	103.3	102.0	85.2
	Local area networks	104.2	102.4	94.5	98.1	99.4	86.1
	Global information networks	102.6	101.4	99.1	100.1	100.0	–
Mining	Personal computers	100.7	102.0	98.0	96.6	98.6	83.6
	Servers	94.6	96.8	185.4	96.1	99.5	78.7
	Organizations with a website	107.5	110.8	107.8	96.8	108.0	79.2
	Local area networks	103.5	101.9	96.1	93.3	99.6	81.4
	Global information networks	100.9	101.8	98.0	96.0	99.2	–
Manufacturing industries	Personal computers	100.3	100.2	99.6	98.5	100.0	87.8
	Servers	111.2	103.7	201.8	104.5	102.1	85.3
	Organizations with a website	104.9	102.5	102.9	102.4	102.6	83.1
	Local area networks	102.9	101.3	96.0	100.9	101.9	86.7
	Global information networks	100.9	100.3	99.9	98.4	100.3	–

Table 2 Economic growth rates of indicators of the use of new technologies and technological innovations in the extractive and manufacturing industries in 2012–2017, % [27]

Type of activity	Indicator	2013/2012	2015/2014	2017/2016
Mining	Growth rate of the share of organizations that carried out technological innovation, %	91.429	89.231	92.727
	Growth rate of the number of new technologies acquired by organizations, %	88.430	78.698	90.250
Manufacturing industries	Growth rate of the share of organizations that carried out technological innovation, %	99.167	99.180	116.102
	Growth rate of the number of new technologies acquired by organizations, %	82.896	87.484	110.680

industry, the growth rate was 7.70%. The intensity of the server use in the manufacturing industry compared to the mining industry is related to the specifics of production and the need to analyze and store big data. In general, the share of organizations that used websites has positive dynamics, but in the extractive industries, the growth rate of indicators is lower than in manufacturing. In terms of the share of organizations that used local computers and global information networks, there was a decrease for the entire analyzed period. This phenomenon is related to the fact that firms are beginning to use servers or outsource the management of their documentation [19, 25]. The extractive industries noted the largest decrease (−3.52%—local area networks; −10.57%—global information networks). In the manufacturing industries, the trend is similar to the changes in the economy as a whole: the decline in the use of local area networks was −2.26% in the manufacturing industry and −2.05% in the economy as a whole; the decline in the use of global information networks was −10.01% in the manufacturing industry and −9.01% in the economy as a whole. The decrease in these indicators is largely due to the cost of using Internet resources, and the location of enterprises and organizations of the mining and manufacturing industry since not all of Russia has high-speed Internet. The above indicators in the manufacturing industries show multidirectional dynamics for organizations using personal computers, local and global information networks, servers, and websites. In industries related to mining, the situation is somewhat different and is characterized by a decrease in the distribution of digital technologies in organizations.

Characterizing the dynamics of the use of new technologies and technological innovations in the industry, one can note that this process is continuous, refers to knowledge-intensive, and its implementation requires a long time (Table 2) [27].

In industrial production, the following key objectives are necessary to effectively implement technological innovation and new technologies: (1) encourage and facilitate companies' access to public funding for R&D, which allow industrial

complex enterprises to implement R&D initiatives based on AI solutions and their use; (2) encourage private investment in R&D through access to various financing alternatives.

5 Conclusions

Structural and technological changes in the Russian industry in this study are considered from the perspective of Industry 4.0 tools, creating modern business models based on the introduction of digital tools that help improve industrial production efficiency. In addition, there is a transformation of the business model, which is defined in terms of the formation of new (digital) markets based on the value network model, which leads to interaction between all market player suppliers and customers.

The proposed theoretical model of digital transformation of the industrial complex involves adapting existing industrial production processes and introducing new technologies through digital design and information modeling. It is necessary to develop and implement modern industrial technologies and technological innovations in the business environment for the effective and competitive functioning of the industry in the global market in an uncertain environment. The introduction dynamics of digital technology in the Russian industrial complex were analyzed based on empirical data using official statistics and other information from open official sources. The analysis of structural changes in the industrial sector of the Russian economy has revealed that it is necessary to work on the transition of the industry to the digital space, involving the entire production chain in specific technological processes and exploiting various innovative technologies, with which decisions can be made to develop a more efficient, balanced and focused on the real needs of the market production chain. It is shown that the introduction of digital technology elements has a positive impact on the transformation of the industrial complex; the ongoing technological changes indicate an important factor in the transformation of the organization mode of economic activity of the industrial complex towards the servicization of the economy.

Thus, the analysis conducted allowed concluding that the development of the industrial complex under digital transformation continues to gain momentum and positively impacts the real sector of the Russian economy. The algorithm and methodology for analyzing the implementation of digital technologies presented in the article can become an instrumental basis for assessing structural changes in the industrial sector of Russia's economy. Further prospective studies will focus on the analysis of digital platforms, changes in the existing business models of the industrial complex in the direction of network structures.

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