NATIONAL RESEARCH UNIVERSITY
HIGHER SCHOOL OF ECONOMICS

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MEASUREMENT OF DIGITAL ACTIVITY IN MEDIUM, HIGH-TECH AND LOW-TECH MANUFACTURING INDUSTRIES

BASIC RESEARCH PROGRAM
WORKING PAPERS

SERIES: SCIENCE, TECHNOLOGY AND INNOVATION

WP BRP 95/STI/2019

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MEASUREMENT OF DIGITAL ACTIVITY IN MEDIUM, HIGH-TECH AND LOW-TECH MANUFACTURING INDUSTRIES

The spread of digital technologies changes production processes and business models, which has important effects for diversification of the economy. The fourth industrial revolution and the Industrial Internet of Things open up new opportunities for the introduction of technologies, having a significant impact on the production cycle, starting with highly automated production lines and ending with the large-scale implementation of technological solutions designed to improve productivity, optimize costs, quality and reliability.

Defining digital transformations, primarily in the manufacturing industry as a strategic imperative for the entire economy, for the first time, based on opinions and intentions of entrepreneurs (short and medium-term), key aspects of the digitalization process in Russian medium, high-tech and low-tech manufacturing industries are revealed. A set of tendencies in the development of digital technologies by their main types is presented, the level of industry participation in digital transformation is shown, as well as many other important digital transformation processes in enterprises that are not measured by quantitative statistics. For all the studied industries, factors hindering digital transformation are identified and ranked.

Keywords: digitalization, digital activity, digital technologies, manufacturing industry, conjuncture observations, digital investment, digital strategy

JEL: O14, O33, L60, O52

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Introduction

1. Background

The current stage of digital transformation is in the active phase and is characterized by breakthrough dynamics of the spread and the implementation of new technologies, changing global markets and the social sphere. Over the following 10 years, the gross value of digitalization in various sectors may amount to more than 100 trillion dollars for society and industry (*World Economic Forum, 2018*). In particular, according to the IDC estimates, global spending of companies on the development of new technologies should grow by 13% up to 2.4 trillion dollars by 2020 (*World Economic Forum, 2018*). It is expected that the main share of these costs will fall on the Internet of Things (hereinafter – IoT) (42%), the mobile and social platforms (25%), artificial intelligence and big data processing (10%), robotic complex (6%) (*World Economic Forum, 2018*).

The transition to a digital economy is connected with an increase in observability, speed, accuracy, flexibility, and, as a result, improved controllability of all production and technological processes. This generates significant macro and microeconomic effects, which include a reduction in the time spent on design and production, a noticeable growth in productivity, an increase in the number of new products and technological systems, profit growth. Companies change business models, become data-centric and dramatically increase the volume of new digital services (*The Center for Strategic Research, 2017*).

It should be noted that the current stage of digital transformation is also characterized by a deep penetration of digital technologies into the value chains in manufacturing, which is reflected in the concept of Industrie 4.0 (*World Economic Forum, 2019*). *The Fourth Industrial Revolution* in manufacturing is a top priority for many business enterprises around the world, as it becomes the driving force of economic growth, opening up opportunities that could not be achieved and realized during the previous revolutions. The shift of manufacturing to digital technology is the basis for creating highly precise, very fast and productive automatically controlled systems capable of mass production of highly customized products (*The Center for Strategic Research, 2017*).

IoT technologies play a key role in these changes (*i-SCOOP, 2018b*). The United States, the Republic of Korea and Sweden are leaders in the development and implementation of IoT (*OECD, 2017*). Manufacturing industry relies on technologies of Industrial IoT (hereinafter – IIoT), undoubtedly playing a leading role in their implementation and investment in development of them (*i-SCOOP, 2018a*). According to Accenture estimates, IIoT should provide a GDP growth of 6.1 trillion dollars or 2% of GDP in the United States by 2030, of 700 billion dollars or 1.7% of GDP in Germany, of 531 billion dollars of 1.8% of GDP in the United Kingdom, of 1.8 trillion dollars or 1.3% of GDP in China (*The Center for Strategic Research, 2017*).

In addition to IIoT, among the technologies, playing an important role in digital transformation of manufacturing, we can mention cloud computing, edge computing[3], machine learning and big data analytics, artificial intelligence, mobile computing, data communication and network technologies, enterprise resource planning (ERP, i-ERP), robotic complex, virtual and augmented reality, blockchain, additive technologies and 3D-printing (*i-SCOOP, 2018b*).

As various studies show, the manufacturing industry is one of those industries that have been moving relatively slowly so far in terms of engaging in digital transformation process (*i-SCOOP, 2018a; McKinsey & Company, 2018c*). Like many other economic activities, in different countries manufacturing is represented by large and small local producers, developing with different potential and speed. In most enterprises, digitalization initiatives are still

[3] Edge computing brings processing close to the data source, and it does not need to be sent to a remote cloud or other centralized systems for processing (*Cisco, 2019*).

fragmented, a holistic picture of change is still missing, although the adjustments are obvious (*i-SCOOP, 2018a*).

At the same time, it is worth noting that, apparently, it is the digitalization of the manufacturing industry that largely determines the leadership of some countries in the field of the digital economy. International experience shows that the higher the level of digitalization, the higher the competitiveness of national economies. For example, according to a McKinsey & Company study (*McKinsey & Company, 2018a*), conducted on the basis of their Digital Quotient global database, companies with advanced digital capabilities grow 5 times faster than their competitors. Among the specific cases mentioned by them is a chemical company that reduced production and marketing costs by 8% because of digitalization, as well as a paper and packaging company that increased ROIC from 6 to 10%, etc.

In the rankings, which identify leaders and outsiders in digitalization, the following countries are shown consistently in the top lines: USA, Sweden, Singapore, Denmark, Republic of Korea, Switzerland, the Netherlands, Great Britain, Norway, Canada, Japan, Germany (*European Commission, 2018*), (*Institute for Business in the Global Context, 2017*), (*Cisco, 2018*), (*IMD, 2018*). For instance, the IMD World Digital Competitiveness Ranking, reflecting the degree of development and implementation of technologies that lead to transformation in government practice, business models and society as a whole, was headed by the United States, Singapore, Sweden, Denmark and Switzerland in 2018 (*IMD, 2018*). Russia in this ranking is on the 40th place, ahead of Saudi Arabia and Italy in comparison with 2017.

The leading countries are already implementing a whole range of large state programs in the field of advanced technologies in manufacturing and other sectors of the economy, designed to launch a new technological revolution (*The Center for Strategic Research, 2017*). For example, in Germany the "National Industrial Strategy 2030" was adopted in 2019, aimed at preserving Germany's status as a world leader in introducing advanced digital technologies in manufacturing (*Federal Ministry for Economic Affairs and Energy, 2019*). In Germany, every fourth company already considers itself "highly digitalized" (*Germany Trade and Invest, 2018*). The manufacturing industry plans to invest around 40 billion euros annually in implementation of Industry 4.0 until 2020, expecting a growth of 153 billion euros during this period (*Germany Trade and Invest, 2018*).

Singapore is planning to extract large benefits from digital transformation by focusing on artificial intelligence and data analysis, cybersecurity, immersive media and IoT. It is expected that by 2021 about 60% of Singapore's GDP will exist within the digital economy (*DBS Group, 2018*).

The United States has adopted the "Strategy for American Leadership in Advanced Manufacturing" and a number of specialized inter-agency initiatives, such as the "Materials Genome Initiative", national initiatives in the field of robotics, etc. (*The National Science and Technology Council, 2018*). In France, national initiatives on the digitalization of manufacturing are based on the "Nouvelle France Industrielle" project (Industrie du Futur) (*Construire l'industriefrançaise du future, 2016*), in the Netherlands – "Smart Industry" (*European Commission, 2017*), in Italy – "Fabbrica Intelligente" (*Cluster Fabbrica Intelligente, 2018*).

The leaders of The Automation Readiness Index among the 25 countries from all over the world studied by the Economist Intelligence Unit are the Republic of Korea, Singapore, Canada, Germany and Japan (*The Economist Intelligence Unit, 2018*).

Since the adoption of the State Program "Digital Economy of the Russian Federation" (*The Russian Government, 2017*) and the "Information Society Development Strategy in the Russian Federation for 2017-2030" (*On the strategy of the development of the information society in the Russian Federation for 2017-2030, 2017*), organizations and enterprises have been actively involved in digital transformation. In particular, one of the objectives of the "Digital Economy of the Russian Federation" program is the successful operation in 2024 of at least 10 industrial digital platforms for the main subject areas of the economy (*The Russian Government, 2017*). With a vast territory and large reserves of natural resources, as well as more than 140

million consumers and huge infrastructure needs, Russia is one of the leading global markets with great potential. In its current state, the Russian industrial sector is ready to take the lead in digital transformation, adapting to new trends and changing realities in the framework of Industry 4.0.

Thus, the escalation of facts and tendencies now leads to an increasing number of discussions regarding the degree of the impact of digitalization on the global economy, the dynamics of development of developing countries and their key segments (*GSMA, 2017*). According to UNCTAD estimates, two-fifths of the economic value obtained using IoT technologies will be accumulated in developing countries (*United Nations, 2017*). At the same time, the world experience and practice of the European Union in the field of the development of the digital economy accumulate annually all new facts showing how significant the economic effect from the introduction of the digital agenda can be.

2. Research problem

The steady spread of digital technologies is changing production processes and business models, which has important implications for both national transformation programs and economic diversification. Although digital technologies can help increase productivity and expand international trade, they also require vision for development inclusiveness, automation planning, and the way in which industrialization is used to promote economic acceleration. Digitalization of manufacturing in many countries raises many economic and social policy issues that need to be addressed based on relevant statistical and analytical information. This determines the necessity to expand the sources of the digital economy measurement and take into account the opinions of the direct participants in the industry-specific digital events – economic agents. It allows obtaining reliable information that contributes to the formation of competent decisions of policy makers aimed at inclusive growth of the national economy based on digitalization.

The growing amount of information containing various aspects of digitalization causes different large-scale events, which not only increase experts' interest in measuring the novelty, complexity and speed of digitalization and its effects, but also emphasize the direct dependence of the success of digital transformation from the availability of accessible, relevant and comparable national sources of statistical data.

The ever-growing number of studies and practical work on this topic evidences the importance and necessity of measuring the level of digital development. Large studies on digitalization are produced by the UN (*United Nations, 2017*), OECD (*OECD, 2017*), World Economic Forum (*World Economic Forum, 2018*), IMF (*IMF, 2018*), ITU (*ITU, 2017*), etc. At the same time, regular information is provided as part of expert studies of major international consulting companies, including market leaders such as McKinsey & Company, PwC, Deloitte, Forrester, which produce reports on the digitization of the economy as a whole and its various industries (for example, manufacturing) (*McKinsey & Company, 2018c*), (*PwC, 2017*), (*Deloitte, 2019*), (*Forrester, 2019*), (*i-SCOOP, 2018a*).

Due to the fact that successful transition to digital technologies largely depends on the scale and capabilities of information content, the development and harmonization of methods for measuring the digital development of enterprises is currently in an active stage in Russia. The importance of research on industrial phenomena related to digitalization, contributing to inclusiveness and sustainability of economic growth, noticeably increases every year. The application of the modern analytical apparatus to the analysis of the information array about digital transformation that is not yet formed will significantly expand the range of insightful research statements and tasks, many of which have not been discussed in Russia before. At the moment, there are outlined ways to solve them.

The sector with high digital potential in Russia is the manufacturing industry, especially if one considers the specifics of the current stage, which is characterized by the emergence of

radical innovations in manufacturing. The manufacturing industry, along with other leading industries of the economy, can become the driving force of economic development through successful involvement in the global digital transformation process that creates new unique opportunities for entrepreneurs. However, at the moment, the inclusion of Russian enterprises in the digital agenda formation program is rather heterogeneous, many transformation projects are still in development, requiring serious investments and improvements. It should noticed that the launched processes of digital transformation, in general, are under the pressure from a large number of influencing factors, are multidimensional and, therefore, are still rather difficult to interpret. It is at the stage of formation that the urgency of rapid measurement of digital trends increases, which is a necessary platform for making the right strategic decisions, as well as corrective actions due to the identification of barriers and restrictions.

In this regard, there is a need for a deeper understanding of both current and future economic development trends and additional opportunities to explore all aspects of digitalization. The ongoing fundamental transformations caused by the growing coverage of various digitalization effects, changing the usual models of production activities, require the rapid identification of new trajectories of the Russian manufacturing industry development, in the context of the technological transformations that are already taking place. These measures are possible with the use of modern and adaptive analysis tools that contain not only quantitative, but also conjuncture measures of the ongoing transformations, which can be developed in the framework of a single digital agenda for statistical observation. In our opinion, business surveys, which are based on aggregate assessments of direct participants in digitalization – entrepreneurs (economic agents), are a necessary link in the successful regulation of digital sectors of the economy.

The complex of key technological solutions, which serve as the basic foundations in manufacturing transformation and form the basis of the digital economy, are currently not fully covered in quantitative statistics in Russian statistical practice and are treated with predictive modeling with a difficulty. The insufficiency of quantitative statistical accounting is especially noticeable in the lack of assessments characterizing the restructuring of business models, the growth dynamics of digital services and the spread of new production architectures that allow linking operational and integration technologies at all levels of production, the development of digital platforms, etc. The main processes of the measured digital economy mainly affect the services sector (healthcare, government, financial services, trade). Against the background of the prevalence of quantitative assessments, the system of primary qualitative indicators of the conjuncture monitoring of digital activity in manufacturing can significantly complement and expand the analytical capabilities of the official standard practices for measuring the digital economy.

In Russia, official statistical monitoring of the use of ICT in business is still reduced to reporting on form No. 3-inform, mainly focused on the OECD business recommendations and Eurostat's experience regarding the so-called first generation, that is, the first-wave technologies, including computerization, process automation, telecommunications. Among the technologies of the second wave (online platforms and cloud computing) and the third wave (predictive big data analytics, IoT, robotics, additive technologies, artificial intelligence, etc.) only cloud computing is taken into account in the Russian statistical reporting. As 3D printing becomes more and more affordable and goes beyond the amateur hobby, more and more attention is paid to how this technology is spreading among manufacturing enterprises today and what impact it can have on simplifying production. This requires a tool for a quick and regular study of the main tendencies, prospects, dynamics of demand and implementation, in order to understand the new ways of industrial application of this technology.

The following areas of business digitalization, such as ICT infrastructure and access, business environment, regulation, information security are also not very informative. There is no comprehensive approach to monitoring digital transformation, which allows for multidimensional measurements of the main directions and factors of the effective use of ICT at

the level of industries and regions. In addition, the current situation with open publications of indicators of the information and digital society development indicates, above all, the lack of a complete set of available indicators with a common method of calculation, generality and harmonization with international standards, which significantly limits the quality of inter-sectoral and inter-regional comparisons with available information in Russia.

The existing incompleteness of information will negatively affect the ability and readiness of any country to use all the opportunities provided by digital development.

In this regard, for the operational and large-scale measurement of the level of penetration of information-digital technologies into the Russian business environment, we used such a method for estimating the existing level of digital activity as conjuncture observations. It is recognized as an effective and reliable source of alternative static measurement of various parameters of economic development of organizations and enterprises.

In particular, based on the results of the "Digital activity of enterprises in the manufacturing industry" conjuncture monitoring, we analyzed the assessments of managers characterizing various aspects of digitalization in general and the level of prevalence of certain digital technologies at Russian manufacturing enterprises in 2018, presenting opportunities that expand the identification of short-term trends. The set of primary indicators of such observation, characterizing more than 1200 Russian enterprises, concentrated in 30 regions of the Russian Federation, undoubtedly, can significantly fill the existing information content. The object of the study consisted of manufacturing industries, representing the medium and high-tech, as well as low-tech manufacturing.

Based on the data obtained, for the first time in Russian statistical practice, a set of tendencies characterizing important processes of digital transformation in enterprises that are not measured by quantitative statistics has been visualized. The main results of the work will reflect the following aspects studied:

- *Focusing on the key priority areas for the development of digital technologies in manufacturing from world practice, we have developed a list of relevant technologies in terms of the level of their actual prevalence (presence) in each of the studied industries. Considering the disruptive nature of additive technologies that can be seen in the example of world industrial leaders who are able to drastically change the existing production organization and provide a range of opportunities not previously achievable in the entire history of manufacturing, we decided to study in more detail the tendencies in the targeted use of 3D printing in Russian enterprises. At the same time, we show the targets of using RFID tags wireless communication technology in the industries - (hereinafter referred to as RFID).*
- *We also worked out the survey results regarding the plans and the readiness of the manufacturing sector managers to introduce digital technologies in 2019, focusing on the specifics of the industrial digitalization processes. In this sense, we found it reasonable to cover the problem of the investment and present tendencies that reveal the current level of investment activity in digital technologies among enterprises, and to show what effects are expected by the heads of industrial enterprises as a result of investment.*
- *We studied additional aspects of digital transformation related to the intensity of the use of digital technologies in business processes and the level of digitalization of labor. We have identified various criteria for evaluating these subcategories of digitalization that were applied to the segregated industries of the manufacturing sector.*
- *Finally, for all the industries under consideration, we identified and ranked factors that impede digital transformation of production.*

Data and Methodology

1. The empirical base of research

The results of the monitoring, containing short and medium-term assessments of the level of digital activity (prevalence of digital technologies) at large and medium-sized Russian industrial enterprises in 2018, became the empirical base of this study. The specially organized conjuncture observation was conducted by the autonomous non-profit organization "Russian Statistics" commissioned by the Institute for Statistical Studies and Economics of Knowledge of the National Research University Higher School of Economics. For the first time in Russian statistical practice, tendencies based on the opinions and intentions of managers of manufacturing enterprises, characterizing the dynamics and scale of digital technologies introduction by main types of technologies, level of industrial readiness for digital transition and actual participation in the process, investment potential, as well as barriers to realization of digital transformation, were detected. The monitoring was performed by self-filling in questionnaires by respondents (directors or managers of enterprises) who have the necessary level of competence regarding the questions asked in the questionnaire.

The territorial bodies of state statistics did the selection of organizations for conducting business surveys independently. In the survey, the total set of units of observation is represented by 1230 enterprises registered in Russia, included in sections B, C, D up to the second level of OKVED 2 classification.

In this paper, the object of study is the manufacturing sector in accordance with the classification of industries and their ranking by technological level. In our opinion, given the specifics of digitalization processes at Russian enterprises in order to monitor digital transformation and the level of digital activity in the manufacturing industry, it was necessary to differentiate the units of observation and the resulting information at the level of separate groups of manufacturing enterprises according to their technological level.

In order to solve the tasks and obtain more detailed results of the conjuncture survey, it is sensible to use the classification developed by UNIDO and recommended for use in the CIS countries[4] (*UNIDO, 2017; Upadhyaya et al, 2016; Kitrar et al, 2016*). It is based on the International Standard Industrial Classification (ISIC) and the Standard International Trade Classification (SITC), as well as the version of the OECD classification adapted to the characteristics of the countries of the region, linking industry expenditures on research and development with value added and production. The classification includes the following technological categories: raw materials processing, low-tech production, medium and high-tech production.

The processing of raw materials consists of activities with a low level of technology, labor-intensive production processes and low capital intensity. Possible competitive advantages of such industries are mainly determined by the presence of local natural resources in the country or by the fact that the skills and technologies used in production can attract capital and promote new technologies.

Low-tech production includes low-tech industries that have fairly simple skill requirements, but are more capital-intensive. In developed countries, the assembly operations of such industries are often transferred to countries with cheap labor and raw materials, while complex production and technological functions are retained within the country.

According to the recommendations of UNIDO, medium-tech and high-tech manufacturing industries for Russia are combined into one group characterized by complex technology and high requirements for personnel qualifications. Medium-tech industries combine enterprises with moderately high level of scientific research and development, requiring complex

[4] The recommendations within the framework of the UNIDO regional project "Improvement of manufacturing statistics and development of statistical indicators for analyzing the development of manufacturing in the CIS countries"

skills, continuous training, adopting "best practices", improving equipment and optimizing composite processes. High-tech industries use advanced technologies that require large investments in research and development, technological infrastructure and the level of special technical skills.

In our study, we embraced industries representing medium- and high-tech, as well as low-tech manufacturing. Table 1 presents the distribution of economic activities regarding the technological structure of manufacturing in accordance with the classification of OKVED 2. The set of industries in the technological categories "low-tech production" and "medium- and high-tech production" corresponds to the recommendations of UNIDO.

Table 1 — Classification of types of economic activity of the manufacturing industry by the level of technology in accordance with the all-Russian classifier of economic activity OKVED2 (2017-2018)

Medium- and high-tech production		**Low-tech production**	
20	Manufacture of chemicals and chemical products (*abbreviated: "Chemicals and chemical products"*)	13	Manufacture of textiles (*abbreviated: "Textiles"*).
21	Manufacture of basic pharmaceutical products and pharmaceutical preparations (*abbreviated: "Pharmaceuticals"*).	14	Manufacture of wearing apparel (*abbreviated: "Wearing apparel"*).
26	Manufacture of computers, electronic and optical equipment (*abbreviated: "Computers, electronic and optical equipment"*).	15	Manufacture of leather and leather products (*abbreviated: "Leather"*).
27	Manufacture of electrical equipment (*abbreviated: "Electrical equipment"*).	19	Manufacture of coke and refined petroleum products (*abbreviated: "Coke and refined petroleum products"*).
28	Manufacture of machinery and equipment not elsewhere classified (*abbreviated: "Machinery and equipment n. e. c." or "M&E n. e. c."*)	22	Manufacture of rubber and plastic products (*abbreviated: "Rubber and plastic products" or "Rubber and plastic"*).
29	Manufacture of motor vehicles, trailers and semi-trailers (*abbreviated: "Motor vehicles, trailers and semi-trailers"*).	24	Manufacture of basic metals (*abbreviated: "Basic metals"*).
		25	Manufacture of fabricated metal products, except machinery and equipment (*abbreviated: "Fabricated metal products"*).
		31	Manufacture of furniture (*abbreviated: "Furniture"*).

Note: *Equivalent nomenclature in English for the names of the industries is partially based on NACE Rev. 2 (Eurostat, 2008).*

2. Methodology

The construction of the digital activity monitoring program in the format of obtaining reliable data, that is, comprehensive, high-quality and comparable in terms of economic activity results of business surveys, was based on international experience in generating and measuring digital progress. The underlying sources in the design of the survey program were:

- the relevant practice of the European Commission (EC) regarding the methodology for creating and implementing a unified digital agenda in Europe aimed at ensuring sustainable economic and social benefits from market digitalization, as well as

conducting annual surveys of the information society (providing part of the statistical data for the "monitoring of the digital economy and society" until 2021, harmonized for all EU member states);

- EC core strategy and platform for digitalization of the European manufacturing industry to achieve the full benefits of a single digital market and digital innovations;
- EC guidelines and plans to assist European manufacturing, small and medium-sized businesses, researchers and government agencies in maximizing the use of digital technologies;
- composite performance indicators combined into the European Digital Economy and Society Index (DESI) (key blocks, construction methodology and results analysis practice).

The survey of heads of manufacturing organizations was conducted on a specially designed questionnaire – "Survey of business tendencies and digital activity of manufacturing", containing 15 integrated thematic blocks of questions corresponding to the following qualitative parameters of activity:

- organization performance indicators (key industry tendencies characterizing the state of the business climate)
- digital manufacturing market (digital development stage, assessment of the current and expected level of digitalization of production, assessment of the impact of digital technologies on production, presence of a digital technology development strategy, investment potential, etc.)
- the level of integration of digital technologies (Internet access and use of the Internet, the use of additive technologies – 3D printing, the use of robotics, the use of cloud services, the use of ERP software, the production processes management (modeling, high performance computing, big data analytics and so forth), computer engineering technologies, etc.);
- human resources \ digital skills;
- the main factors hindering the introduction and use of digital technologies.

In general, the system of indicators and the structure of relevant issues in the survey program are based on the following standard methodological principles going from the recommendations of the Organization for Economic Co-operation and Development (OECD) and the Statistics Department of the European Commission (EC):

- questions relate to the characteristics of the activities of the organization directly surveyed;
- questions reflect the dynamics of indicators for the year;
- on all issues related to the assessments of the dynamics (tendencies) of indicators, a three-category graduation is used: the number of respondents indicating growth (improvement) (+), no change (=), decline (deterioration) (-), respectively;
- all information obtained in the process of conjuncture survey is of a qualitative nature.

Conjuncture observations are a method of collecting information from a certain number of units or individuals that make up a sample in order to make sensible conclusions about main tendencies in a change of the statistical population. An objective advantage is the ability to receive digitized answers from the economic community to many key questions related to short-term features of industrial functioning, which are often not reflected in official quantitative

statistics. Traditional quantitative statistics show changes in objective conditions, while qualitative survey data show how economic agents interpret and evaluate these changes.

Thus, based on the methodology for conjuncture survey programs, which imply ordinal scales with three gradations, the gradations of "increase", "no change" and "decrease" are used for the metric representation of the tendency of each indicator of business activity, and the gradations of "above normal", "normal" and "below normal" are used for the representation of the current level of each indicator.

Consequently, the analysis of the results obtained consisted of the traditional measurement and ranking of the intensity of development or the prevalence of one or another aspect of the observation (indicator). Analytical interpretation of the digitalization processes of manufacturing enterprises was represented in the user-friendly visualization, which in real time characterizes the current and expected business tendencies in terms of changes in digital activity.

Considering that now there are many alternative methodological approaches to measure and present the results of measuring the effects and processes of digitalization, we decided to use some of them additionally for our tasks, adapting them for the Russian practice of measuring digital activity. In particular, along with the traditional methods of the analysis of nonparametric information, we used the McKinsey & Company approach to measure *the level of real usage of digital technologies in business processes and the level of digitalization of labor* (*McKinsey & Company, 2015*). We found an interesting the approach in which they divide the digital activity indicators into three categories: "digital assets", "digital usage" (digital technologies usage in business processes) and "digital labor". They proposed this classification within the framework of the MGI digitalization index methodology for 22 sectors of the US economy (*McKinsey & Company, 2015*). Due to the fact that we are working with qualitative nonparametric indicators, we decided to exclude the indicator of "digital assets", for an adequate measurement of which data are necessary in quantitative form. One of the results of the McKinsey & Company study was that it is the digital usage and the digital labor that are key to the digital transformation of industries, so excluding this category seems acceptable. We decided to rely partially on this division method, adapting it for the Russian practice of measuring digital activity. The study of digital transformation in this differentiated form turned out to be important for identifying specific aspects of digitalization that need additional attention from business and government.

At the same time, we used the experience of World Economic Forum analysts, who, along with the general economic trends in the field of digitalization, examined the industry features of digital transformation, relying, among other things, on cases of individual companies – industry leaders (*World Economic Forum, 2018*). For example, in the automotive industry, they identified three technology trends: "connected travellers", implemented by Jaguar, autonomous driving technologies developed and implemented by Volvo, GM, and fully integrated digital enterprises created by Michelin, Tesla, Audi (*World Economic Forum, 2018*). As a result, our study is also accompanied by relevant examples and cases of digital transformation of Russian companies.

Thus, our chosen methods for analyzing and presenting the survey results combine elements of existing methodological approaches, adapting them to study the Russian manufacturing industry. As a result, our research focuses not only on identifying global trends through digitized assessments of respondents, but it also details and identifies key tendencies and features that characterize various aspects of digital transformation in enterprises.

Findings

1. The prevalence of digital technologies in the manufacturing industries

In this section, we examined digital technologies for the current level of prevalence at Russian manufacturing enterprises in 2018. The results of the analysis are presented in accordance with the industry classification and the division by technological level (fig. 1, fig. 2).

On the basis of the survey questionnaire, the following nine technologies were identified, the implementation of which in the production was stated by the respondents interviewed: *intellectual robotic complexes; additive technologies; 3D printing; open manufacturing technologies; cloud computing; manufacturing analytics technology; IIoT; big data processing technologies; RFID.*

Within each studied technology, the industry samples were divided into three segments, according to the "high", "medium" and "low" level of prevalence. The principle of this division was the expert ranking of the sample by the size of the share of respondents who indicated the implementation of a particular technology. The industries with the highest coverage recieved a "high" level of the technology prevalence, with the medium coverage – "medium", and with the low coverage – respectively, "low".

According to the presented visualization (fig. 1), in the medium and high-tech industries, the leading technology in terms of a high level of presence in the industry was IIoT. It was within this technology that the largest number of industries were concentrated, among which were computers, electronic and optical equipment, electric equipment, chemicals and chemical products, motor vehicles, trailers and semi-trailers.

In particular, the manufacture of computers, electronic and optical equipment covers all technologies and is evenly distributed at medium or high levels. This industry, by its very nature, is at the forefront of digital transformation. Opportunities for the relatively rapid modernization of production processes in it provide a high speed of the spread of digital technologies.

In addition to IIoT, the technologies that accumulate a great number of industries in the high-level segment should include *intellectual robotic complexes, the manufacturing analytics technology and RFID.*

It should be noted that *intellectual robotic complexes*, as well as IIoT, were most prevalent in enterprises producing computers, electronic and optical products, motor vehicles, trailers and semi-trailers and electrical equipment. At the same time, a high level of involvement of *the manufacturing analytics technology* can be seen in the chemical industry, pharmaceuticals and the production of machinery and equipment n. e. c.

Pharmaceuticals, the motor vehicles industry and the production of machinery and equipment n. e. c. became industries with a high level of the *RFID* technology prevalence. In the case of the pharmaceutical industry, the observed tendency is largely determined by government policy. Since 2014, when the decision was made on the need to create a unified labeling system to control the movement of goods in the territory of the Eurasian Economic Union (EAEU) member countries, government projects are implemented annually to introduce product labeling in various industries using RFID (*TAdviser, 2018*). The pharmaceutical industry has become one of the industries most affected by these projects.

In addition to the use of RFID and the manufacturing analytics technology, the specific nature of the pharmaceutical industry was the low level of prevalence or the complete absence of all the remaining technologies. Probably, this can be associated with longer periods of introduction of new technologies in the direct production processes in the industry. Despite this, the following sections of our study show that the perspectives for pharmaceuticals in the development of digital technologies are rather favorable due to the high level of investment activity in this area.

Further differentiation of industries within the segment of high involvement of the remaining technologies shows that *additive technologies* and *3D printing* were common in the

motor vehicles industry and the computers, electronic and optical equipment production. It can be expected that in the near future additive manufacturing will develop at an active pace. Manufacturers of necessary materials and industrial 3D printers have already appeared in Russia, a large number of developments has been accumulated and the additive industry is included in the government technological agenda (*VIAM, 2018; J'son & Partners, 2019*).

Big data processing technologies spread in the high level in the electrical equipment production and the manufacture of machinery and equipment n. e. c. *Cloud computing*, according to the results of the conjuncture survey, was most often used in the production of machinery and equipment n. e. c. and the chemical production.

In accordance with the revealed tendencies, *open manufacturing* turned out to be relatively less common in Russian manufacturing. The exceptions were enterprises for the production of electrical equipment and motor vehicles, having settled into the segments indicating high and medium levels of prevalence, respectively.

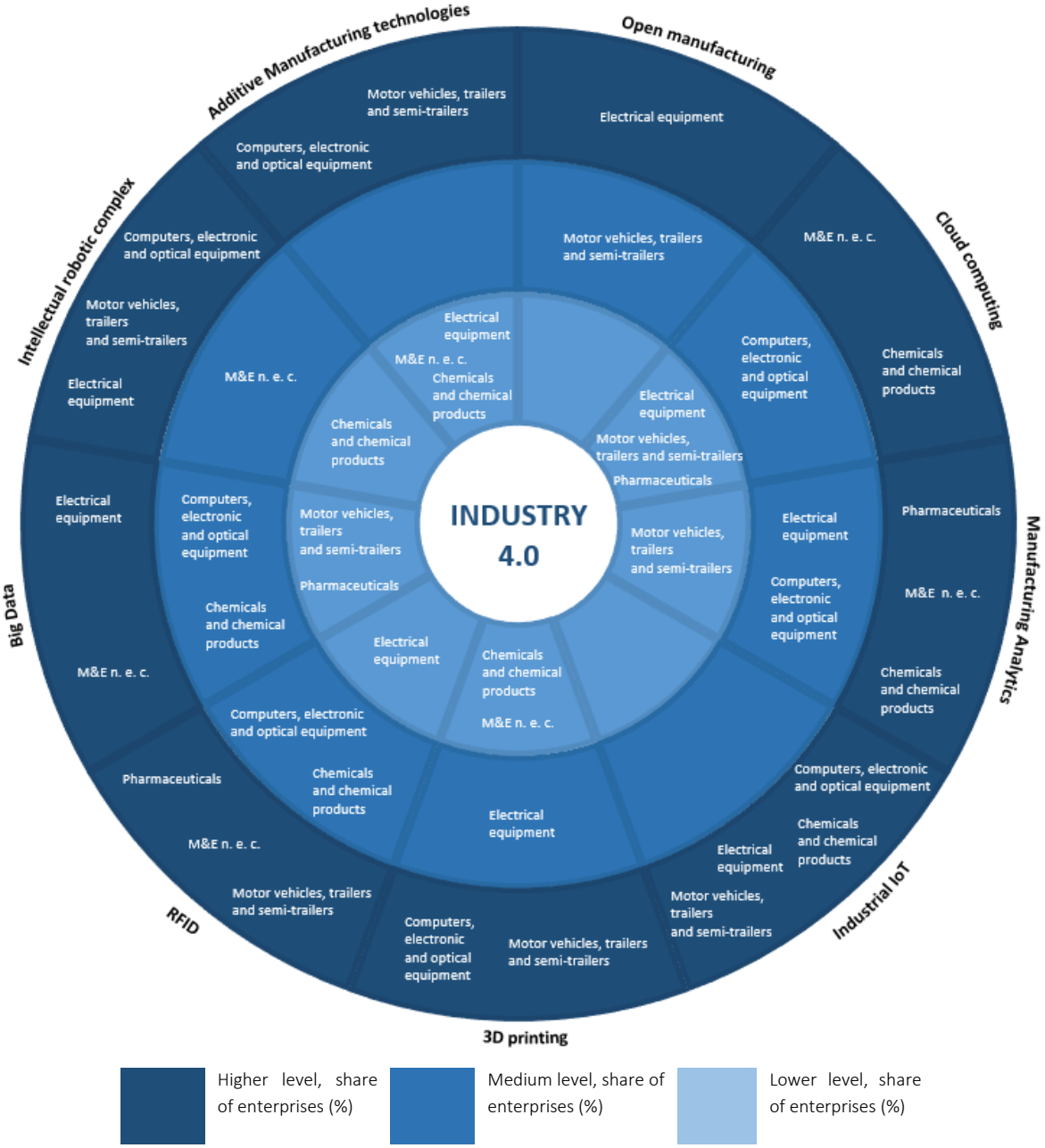


Figure 1 — Ranking of medium and high-tech industries by the level of prevalence of digital technologies

Let us move to the level of the digital technologies prevalence among a group of low-tech industries (fig. 2). *Cloud computing* has become the most common in the low-tech segment. As shown by the results of the survey, this technology was used at a relatively high level in three sectors at once — the production of basic metals, fabricated metal products and rubber and plastic products.

The following relatively common technologies were intellectual robotic complexes, big data and RFID, which were present at a high level in the industries of fabricated metal products, rubber and plastic products, leather, as well as coke and petroleum products.

As the analysis showed, the manufacture of fabricated metal products in the low-technology segment has become the industry that is most susceptible to digital technologies, being present in all technologies at a high level, except for IIoT. Moreover, it has become the only industry present in *open manufacturing* technologies.

Manufacture of basic metals was predominantly characterized by the medium level of prevalence. At the low level, industrial enterprises for the production of textiles, furniture and leather were mainly concentrated.

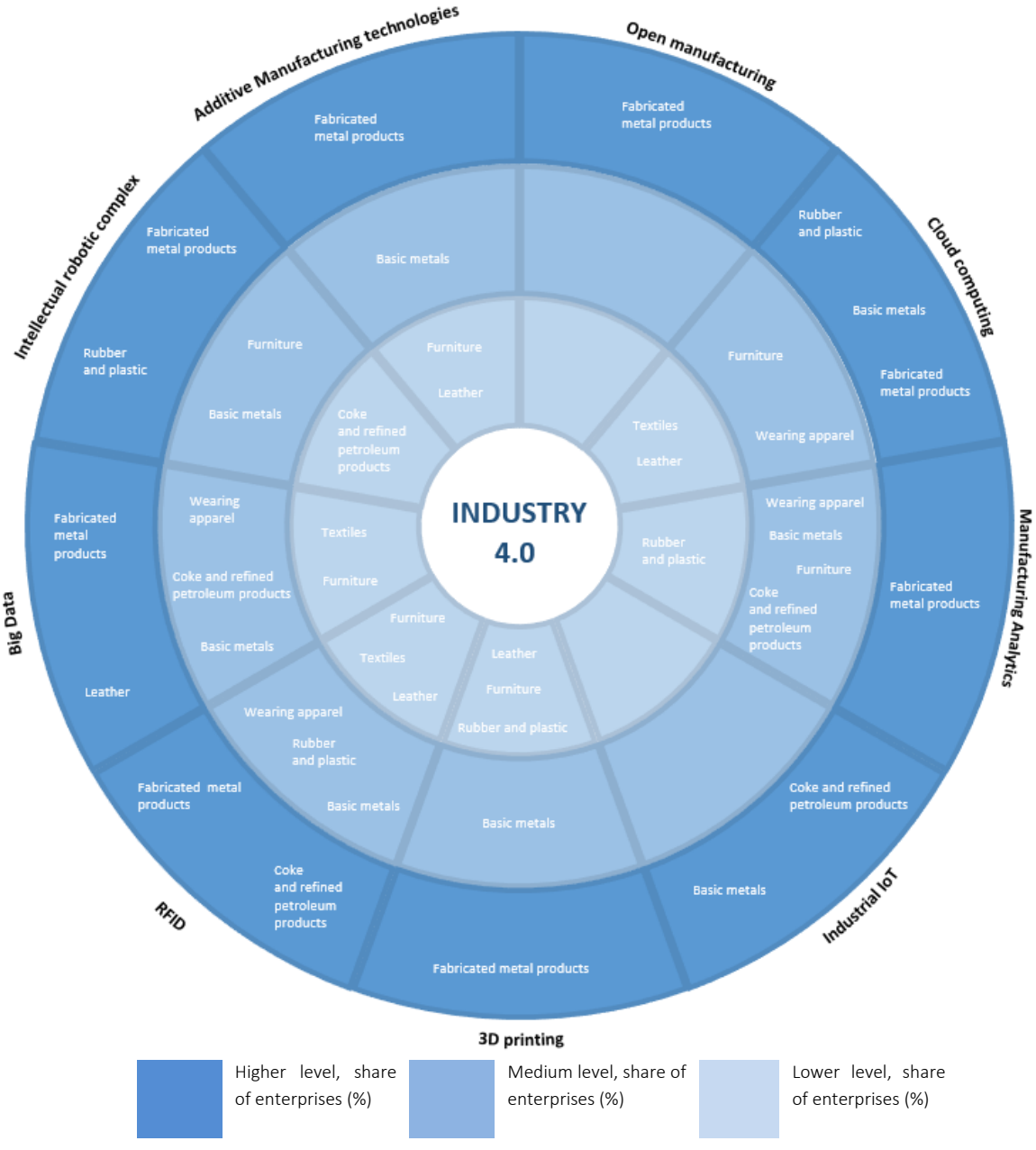


Figure 2 — Ranking low-tech industries by the level of prevalence of digital technologies

The conjuncture survey program also allows to measure the level of digital activity, as well as the presence of a strategy in the field of digital technologies in enterprises. Taking into account the analysis of the level of the digital technologies prevalence on production, we considered it important to identify and demonstrate in detail the characteristics of the distribution of industries in accordance with their digital activity and the digital strategy.

To do this, we identified two sets of the survey results, the first of which includes industry-wide assessments of managers characterizing their own digital activity as “high”, and the second – the proportion of respondents who stated about the presence of digital technology strategy. The analytical interpretation of the results is visualized in Fig. 3. Accordingly, the abscissa axis reflects the assessments of respondents with a “high” level of digital activity, and the ordinate axis represents the shares of enterprises that had a strategy in the field of digital technologies.

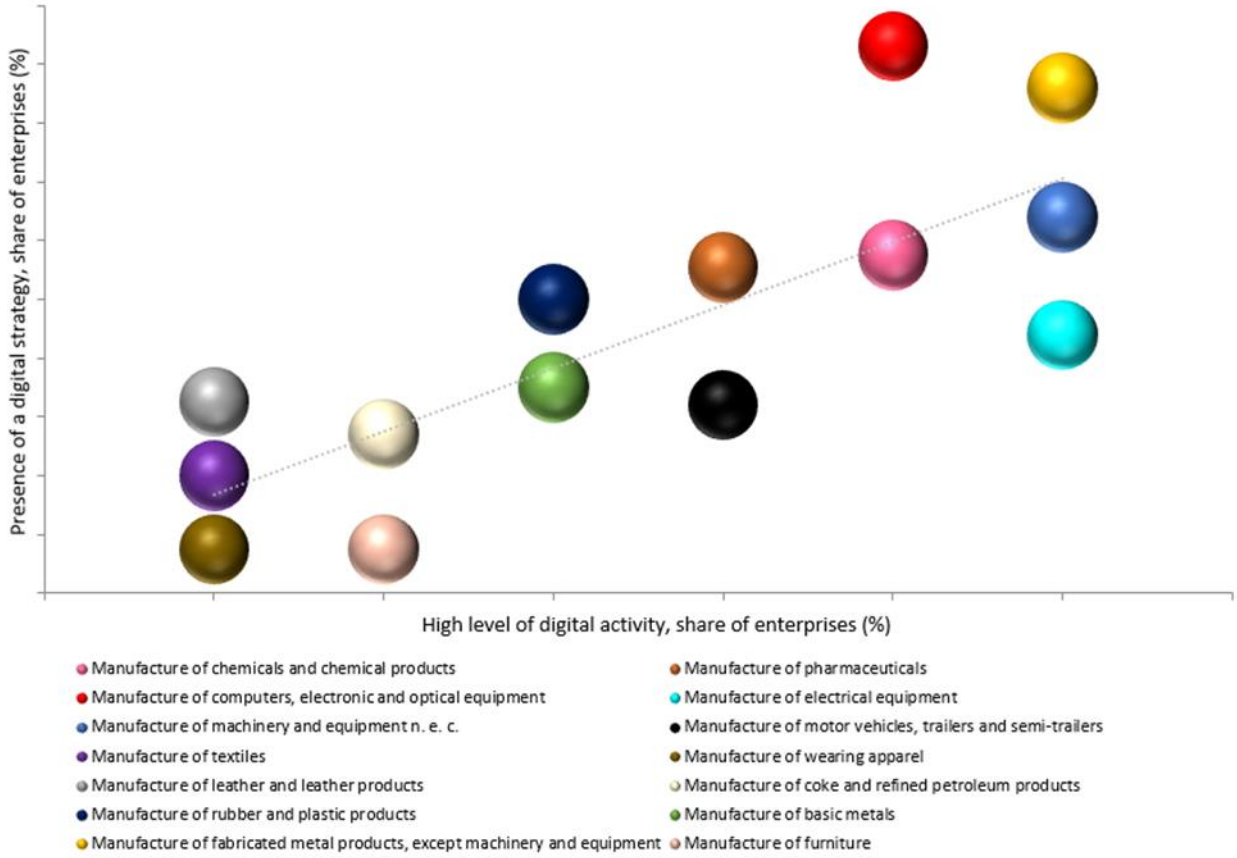


Figure 3 — Distribution of manufacturing industries in accordance with the level of digital activity and the presence of a strategy in the field of digital technologies

The group that included the maximum shares of both enterprises with high digital activity and the enterprises with the developed digital strategy consisted of computer production and production of fabricated metal products, which is quite consistent with the results of the ranking of industries by the level of digital technologies prevalence. A slightly lower concentration of such enterprises was represented by manufacture of machinery and equipment n. e. c., chemicals and pharmaceuticals. The electrical equipment industry stands alone, where, against the background of a fairly high level of digital activity, the concentration of industries that operate on the basis of a digital strategy is only at a medium level. Finally, the group that accumulated the smallest share of enterprises with a high level of digital activity and a relatively small share of enterprises that had their own digital strategy included the production of leather, textiles, wearing apparel, furniture, as well as coke and petroleum products.

In general, the existing distribution partially overlaps with the tendencies represented by Fig. 1 and Fig. 2, although there are some exceptions. It can be assumed that the directors’

perception of their own digital activity depends largely on their general understanding of the situation and the strategy for further development. The number and variety of digital technologies being introduced can sometimes be less significant, as can be seen, for example, in the case of pharmaceuticals: in the previous section, this industry was among those with the least amount of digital technologies at high and medium levels, but this did not negatively affect directors' perceptions in terms of their digital activity.

2. 3D printing and RFID targeted use tendencies

Based on the capabilities of the information content of the conjuncture observation results, we have examined and visualized the tendencies in the targeted use of two technologies of current interest in enterprises: 3D printing and RFID. For this task, we ranked the targets of applying these technologies in enterprises among industries where their use is common, based on the proportion of respondents who had indicated one or another target presence.

The results of a study of the targeted use of 3D printing are presented in Fig. 3. One of the most common targets was the production of prototypes or models for internal use. Visualization allows us to state the presence of the phenomenon in every industry, with the exception of furniture production.

The production of prototypes or models for sale, goods and parts of goods for sale as targets turned out to be relatively less common practices of using 3D technologies, but they are presented in such industries as the manufacture of computers, electronic and optical equipment, machinery and equipment n. e. c., rubber and plastic products, basic metals, furniture and fabricated metal products.

Worldwide, the main goal in the field of additive manufacturing is considered to be the transition to the active use of additive technologies for the manufacture of real goods and parts for sale (*Additive Technologies, 2019*).

As you can see, additive technologies are currently being introduced predominantly for auxiliary domestic production in Russia; however, along with the expected strong development of additive technologies in Russia in the near future, there is a likely tendency to increase the role of 3D printing usage for the manufacture of real goods and parts of goods.

Promotion of additive technologies is a task set in Russia at the government level. In accordance with the instructions of the Government of the Russian Federation, the Military Industrial Commission, and the Ministry of Industry and Trade of the Russian Federation, the "Comprehensive action plan for the development and implementation of additive technologies in the Russian Federation for the period 2018–2025" was developed. The document was developed on the basis of the All-Russian Institute of Aviation Materials with the participation of the state corporations Rosatom, Rostec, Roscosmos. The plan has several areas of implementation, including the creation of digital additive manufacturing enterprises, the development of domestic materials of a new generation and additive manufacturing techniques for parts for sale, the development of additive technologies for the production and use in the medicine (*VIAM, 2018*).

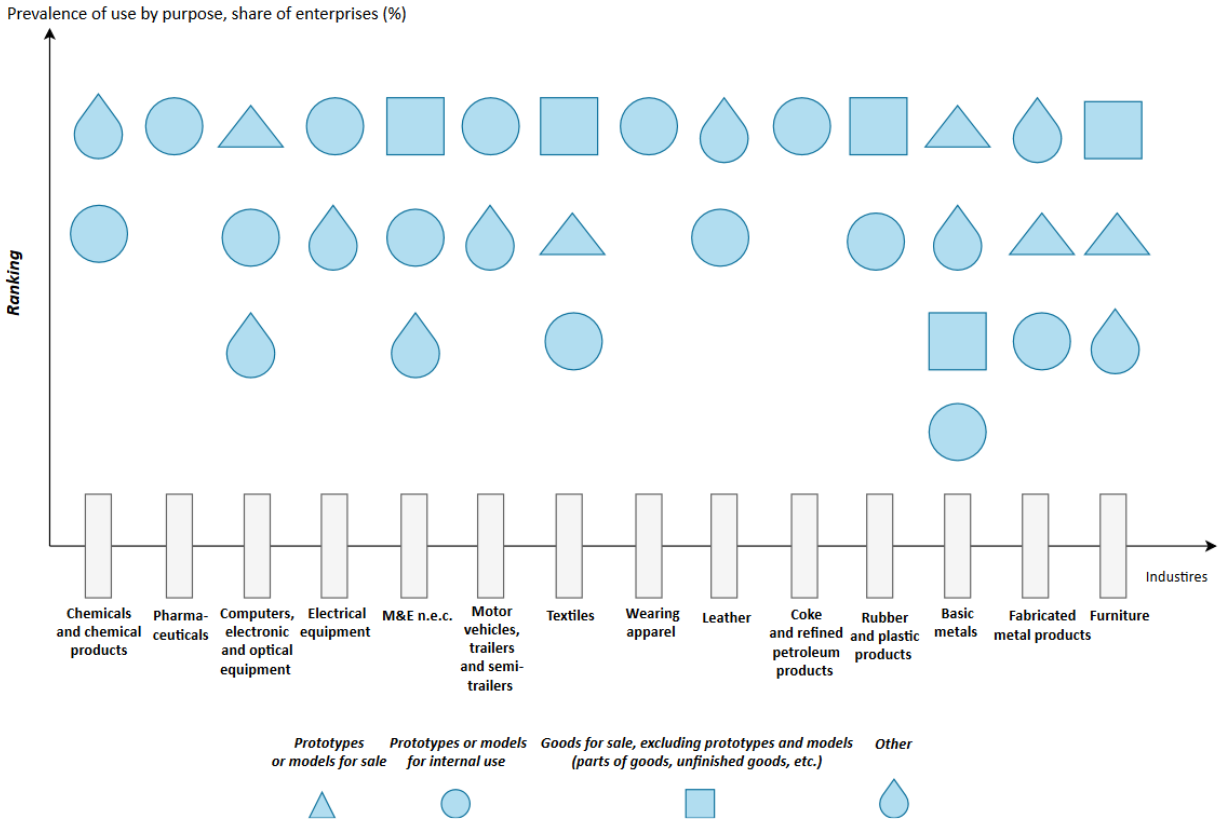


Figure 4 — Ranking the targets of 3D printing technology use in manufacturing enterprises by the prevalence of use

Let us examine the established priorities for the use of RFID in manufacturing enterprises. The results of a study of the level of use and coverage of this technology for various targets are presented in fig. 5.

In the conjuncture survey, three main ways of their use were considered: in the process of production and delivery of goods, for identifying goods after their production and for identity identification for access control. The Russian market of RFID technologies is in its infancy and occupies a small amount in global sales (*J'son & Partners Consulting, 2018*), but most industries in the Russian manufacturing industry have experience in implementing this technology for all the three identified goals. Until 2020, the Government of the Russian Federation adopted a program to introduce mandatory labeling on 12 items, and until 2024, it plans to cover almost all mass-produced goods. In the experiment, medicines, shoes, fur coats and tobacco are now marked. Since July 2019, new projects have started in the system of labeling and tracing of goods: the registration of participants in the drug circulation system of the high-cost nosologies program begins, the production of unmarked tobacco products is stopped, a voluntary experiment in the perfume industry begins. In July, the shoe labeling project enters a new phase.

According to the survey results, RFID as a whole demonstrated a sufficient scale of presence in enterprises regardless of the targets of use. However, RFID is most often used as part of identity identification for access control around all the examined branches of the manufacturing industry, with the exception of furniture production.

At the same time, the highest level of use of the labeling system was occupied by the other two targets: product identification and the delivery of services or goods. In particular, RFID was involved in the identification of industrial products in six industries: the production of chemicals and chemical products, computers, electronic and optical equipment, electrical equipment, motor vehicles, textiles, wearing apparel. In the production of machinery and equipment n. e. c., coke and petroleum products, furniture, rubber and plastic, the highest level of RFID use was observed in the delivery of services or goods.

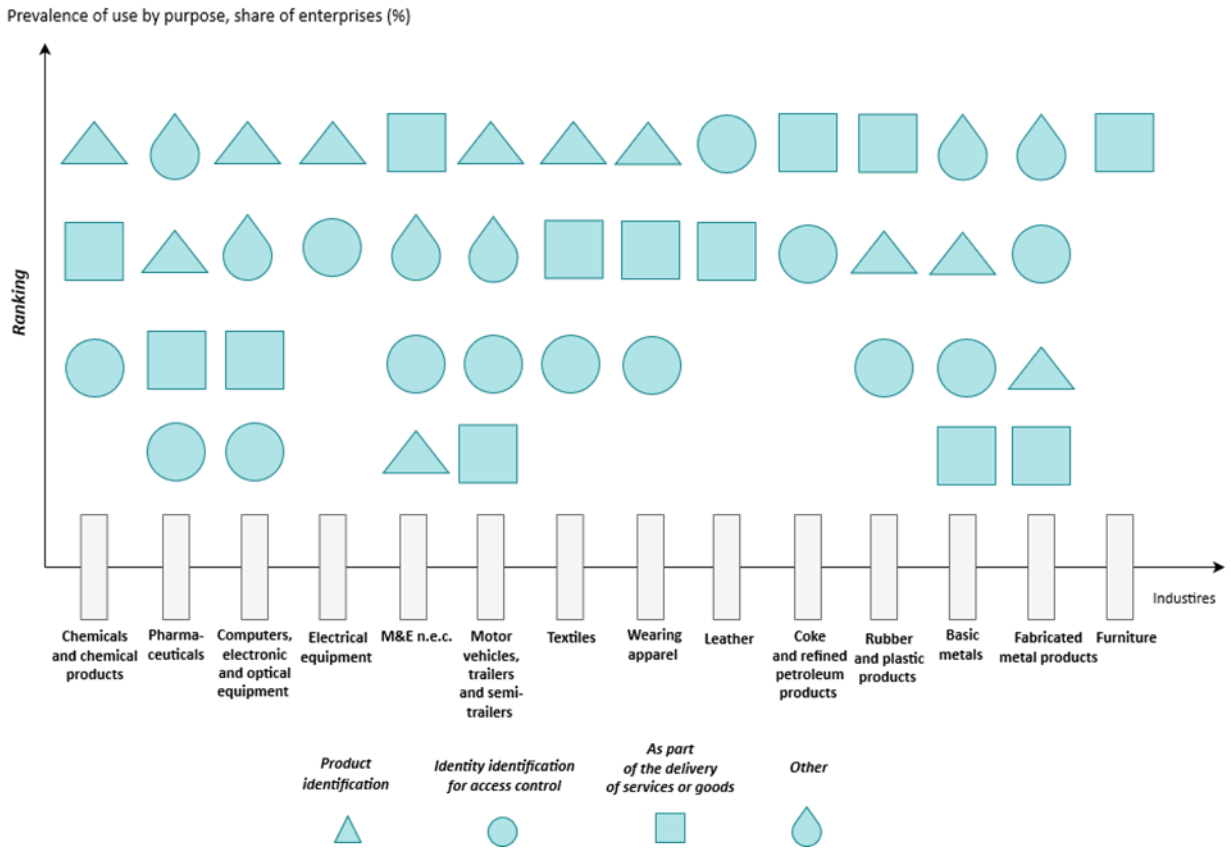


Figure 5 — Ranking the targets of RFID technology use in manufacturing enterprises by the prevalence of use

3. Planned for implementation (developed) digital technologies

In this section, we will look at digital technologies that are planned for implementation in the segments of the manufacturing industry in the short term (fig. 6, fig. 7). At the same time, we considered it important to rank the technologies in terms of the greatest demand for the development that had set in each of the industries, disposing them in descending order according to the assessments of enterprise managers.

According to the data obtained, in the medium and high-tech segments, the first positions in six technological rankings were taken by 3D printing, additive technologies, IIoT, the digital workplace and cloud computing.

At the same time, among all the industries it is difficult to distinguish any technologies that are given an evident preference, which can be explained by the specifics of the economic activities. In particular, despite the active promotion of IIoT, this technology was the most popular among the others only in the motor vehicles, trailers and semi-trailers industry. In the other industries, IIoT was in the middle or at the bottom of the rankings. At the same time, manufacturing analytics, as technologically close to IIoT, were relatively popular in the motor vehicles, chemical and electrical industries. 3D printing and additive technologies were in demand in the manufacture of electrical equipment, machinery and equipment n. e. c., computers, pharmaceuticals. The digital workplaces received increased attention in chemicals, in the motor vehicles industry and computer production.

It should be noted that pharmaceuticals were leading in projects to develop solutions based on cloud services and intelligent robotic complexes. In the other industries, these technologies turned out to be less popular.

For the production of machinery and equipment n. e. c., it was necessary to develop solutions based on end-to-end automation and open manufacturing, while for computer production the most important technologies included open manufacturing and 100% utilization

and recycling. Much attention was paid to the development of technologies for 100% utilization and recycling in chemical production.

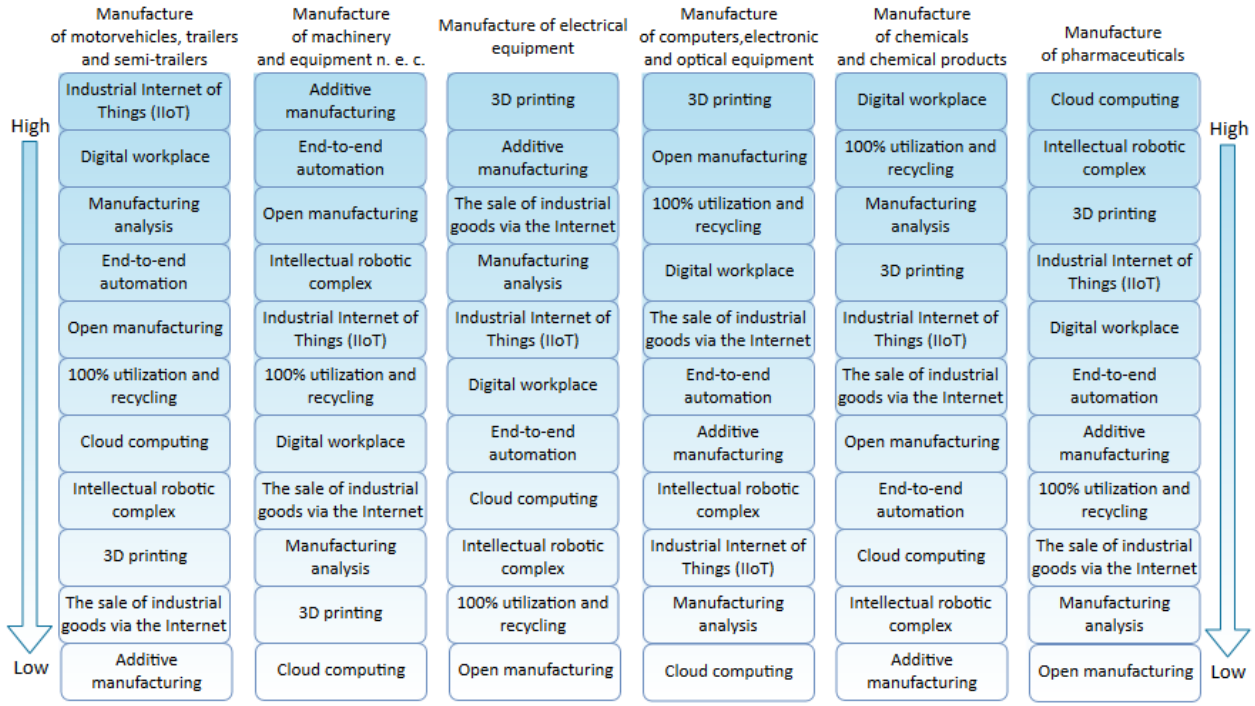


Figure 6 — Ranking of technologies planned for implementation (developed) in 2019 in the medium and high-tech manufacturing industries

Let us turn to the industries in the low-tech segment now (fig. 7). Along with additive technologies and 3D printing, technologies such as 100% utilization and recycling, the sale of industrial goods via the Internet and end-to-end automation were at the top of the eight ratings. This can be explained by the specifics of the low-tech segment, for which the introduction of the advanced technologies of Industry 4.0 is less in demand at the present stage of digital transformation. For example, IIoT technology turned out to be relatively popular only in the production of fabricated metal products, while in the other rankings it is concentrated in lower positions or is at the bottom, as for example, in leather and textile production. At the same time, the manufacturing analytics technologies play an important role among the planned to implementation technologies in the basic metals production and the production of coke and petroleum products. In addition to basic metals and fabricated metal products, where 3D printing and additive technologies, respectively, occupy the first places in the rankings, in the other industries, these technologies are mainly of medium popularity.

In the manufacture of furniture, basic metals, the production of rubber and plastics, projects for the development of solutions based on end-to-end automation are common; in the manufacture of leather and textiles – projects in the field of open manufacturing; 100% utilization and recycling projects are popular in the production of coke and petroleum products, textiles, leather and wearing apparel; the digital workplaces were important for the of coke and petroleum products industry and the rubber and plastic industry. In addition, in the sectors of wearing apparel, furniture and rubber and plastic products, there is a great interest in solutions for the sale of industrial goods via the Internet, which may be due to the greater involvement of these sectors in the electronic trade in consumer goods.

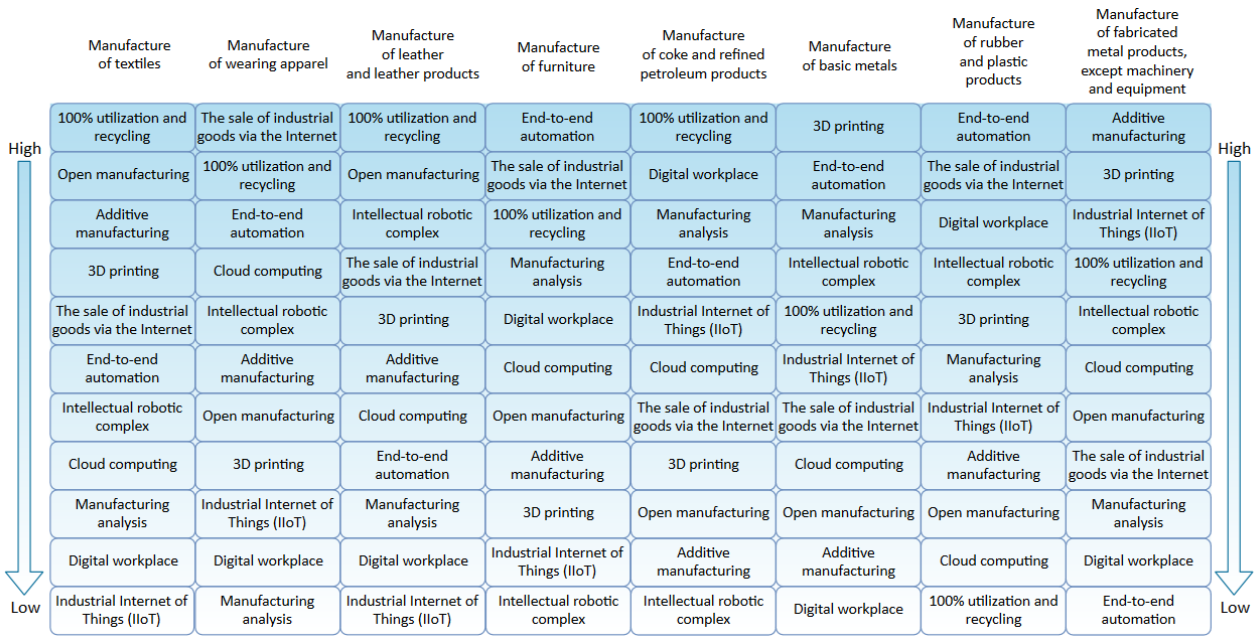


Figure 7 — Ranking of technologies planned for implementation (developed) in 2019 in the low-tech manufacturing industries

4. Industry expectations from investing in digital technology

In the current section, we analyzed the survey results to demonstrate the differentiation of industry expectations from investing in digital technology. We examined which of the expected benefits are more or less important within different industries where an active position in investing in digitalization was observed.

The resulting tendencies are reflected in the industry ranking by the aggregate of enterprises whose managers characterized the current level of investment in digital technologies in 2018 "above the normal level"[5], as well as their estimative opinions on the most important benefits they rely on primarily after financial investments in digital technology. The benefits, which were mentioned by a relatively larger share of enterprises, were recognized as more significant, a relatively medium share – moderately significant, a relatively small share – less significant. Manufacturing industries were examined separately in two groups: medium and high-tech industries (fig. 8) and low-tech industries (fig. 9).

In the medium and high-tech industries, according to the current level of investment in technology, machinery and equipment n. e. c., pharmaceuticals, and the motor vehicles industry had taken the lead. The manufacture of chemicals and chemical products closed the ranking.

In the production of machinery and equipment n. e. c., they expect a maximum range of benefits from investments in digitalization: production growth, improved customer service, increased competitiveness and profits, environmental friendliness increase, expanding the customer base and optimizing the number of employees. In the pharmaceutical industry, the situation is different. The industry has a clear focus on improving competitiveness, for which, first of all, investments are made. Apparently, this may be due to the need to compete with foreign companies dominating the import-oriented Russian pharmaceutical market (*DSM Group, 2019*), as well as the recent increase in competition for consumers in the market (*Deloitte, 2018*).

A large level of digital investment in the pharmaceutical industry is largely linked to government policy. According to the Ministry of Industry and Trade of the Russian Federation, more than 150 billion rubles were invested in the pharmaceutical industry in 2011–2017, of

[5] "Normal level" - normal, acceptable at the time of the survey.

which about a quarter is accounted for by government investments *[Ministry of Industry and Trade of the Russian Federation, 2018*]. The priority directions of the state policy in the pharmaceutical market are import substitution, the implementation of a project to introduce a drug labeling system, the development of a state supply system with essential medicines and support for bioclusters, such as Skolkovo and the Kaluga pharmaceutical cluster (*Deloitte, 2018; McKinsey & Company, 2018b*).

In the motor vehicles industry, the main benefit from investments in digital technologies is the optimization of the number of people employed due to the robotization of low-skilled personnel. It is followed by productivity growth and cost reduction.

In the manufacture of electrical equipment, the most important benefits are the increase in labor productivity, profits, expansion of the customer base and robotization of low-skilled staff. In the manufacture of computers, electronic and optical equipment – the growth of production, manufacturing defects decrease and the expansion of the customer base.

The feature of chemical production, where the smallest number of enterprises had a high level of digital investment, is that one of the most important expected benefits is the increase in environmental friendliness.

For all manufacturing enterprises as a whole, the main expected results from the implementation of digital projects were increased productivity, reduced costs and improved customer service (*ISSEK, 2018*).

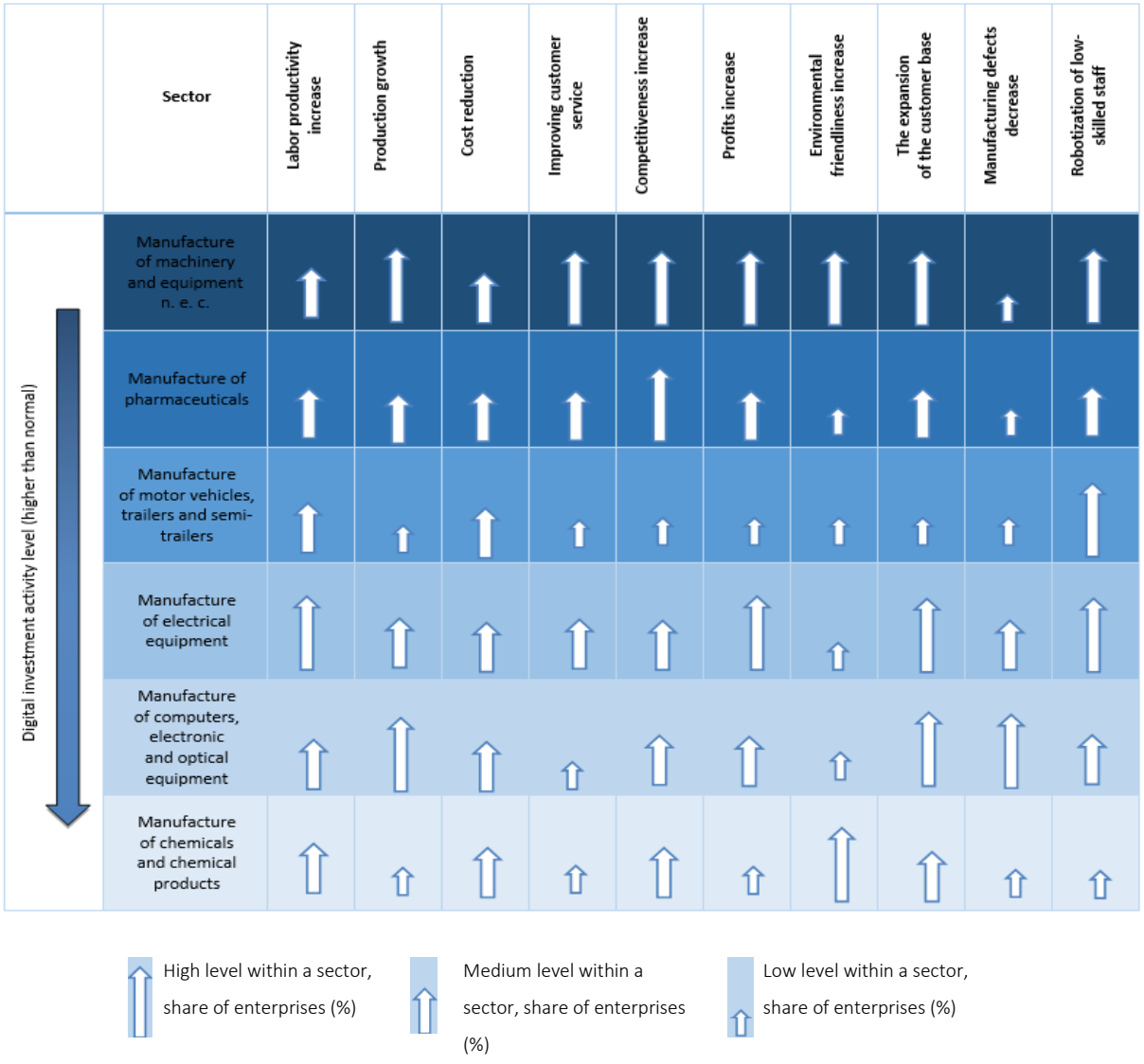


Figure 8 — Ranking of the expected effects of digital investment in the medium and high-tech manufacturing industries

If we look at the low-tech manufacturing industries, then the top three in terms of the share of enterprises with the level of investment in digital technology "above normal" included the production of fabricated metal products, basic metals and the production of coke and refined petroleum products.

In the production of fabricated metal products, the main benefits are associated with an increase in production and a decrease in manufacturing defects, while in the manufacture of basic metals, along with these indicators, improvement of customer service and expanding the customer base stand out as the most significant benefits.

As for coke and refined petroleum products, this industry has a profile similar to chemical production: environmental friendliness is considered the most important benefit. The first automated air monitoring system in the country's oil refining industry was created at the Moscow Refinery in 2015 as part of the environmental modernization program of the plant (*Gazpromneft MNPZ, 2018*). It includes sensors located directly on facilities that process and transmit data to city and federal supervisory authorities all the time and allow receiving real-time information about the air quality in the enterprise.

Respondents from the rubber and plastics industry mention increased customer service, increased competitiveness, increased profits and reduced manufacturing defects among the important benefits. For manufacturers of leather products, the main benefit from digitalization is an increase in production, and for furniture manufacturers – an increase in profits. Finally, for the production of textiles and for the production of clothing, the main benefit from investments in digital technology is the expansion of the customer base.

In general, in the low-tech segment of the manufacturing industry, the most popular indicated benefits were the increase in production, the increase in profits and the decrease in manufacturing defects. The expansion of the customer base turned out to be less significant relative to the situation in the medium and high-tech segment, however, due to its popularity in the least digitalized production of textiles and clothing, it also retains its importance among low-tech industries. The expansion of the customer base was less significant compared to the situation in the middle and high-tech segment; however, due to its popularity in the least digitized industries of textiles and wearing apparel production, it also retains its importance among the low-tech industries.

Figure 9 — Ranking of the expected effects of digital investment in the low-tech manufacturing industries

5. The usage of digital technologies in business processes and the digitalization of labor

Digital technologies radically change the speed of information processing, methods of data collection, storage and exchange. The main trends of the digital economy are connected with the emergence of new business models and the reshaping of old ones because of the possibilities of using digital technologies and digital infrastructure. In addition, as a result of digitalization, there is a rapid transformation of the labor market: digital skills and competences become crucial. Due to the fact that among enterprises of different types, digital transformation occurs at different speeds and in different forms, we can often observe the existence of a digital gap between them. It can be expressed both in differences in the degree of penetration of digital technologies into business processes, and in usage of qualitatively different digital technologies in different industries. Therefore, studying the usage of digital technologies in business processes and the degree of digitalization of labor in a differentiated industry context is important for understanding the existing digital gap.

Because of the topicality of these issues it was important for us to find out, on the basis of the obtained survey results, what criteria for digital transformation and to what extent determined the usage of digital technology in business processes at the moment, and which of them became significant to digitalization of labor in manufacturing in 2018 (to solve these problems, we used the McKinsey & Company approach, described in detail in the methodology section (*McKinsey & Company, 2015*)). In particular, to solve each of the tasks, we focused on the criteria, expertly selected from the survey questionnaire, the most relevant to two categories – "digital usage" and "digital labor".

The following indicators were selected as the criteria for the "digital usage", the level of which the managers rated "above the normal level": "use of cloud services", "information exchange in electronic form at the enterprise", "information exchange in electronic form with other enterprises (consumers/contractors)", "electronic invoicing", "electronic commerce turnover", "Internet access and usage of the Internet for business purposes at the enterprise", "usage of personal computers, laptops, tablets and other portable devices" (table 2). Some criteria come into contact with the digital technologies from the first section (fig. 1, fig. 2), but it is worth noting that here we are considering the same technologies through another prism. If in the first section we relied on data on the number of enterprises, where at least to some extent there was experience in implementing a particular technology, then in this section we use data on the number of enterprises indicating high intensity of technology use or widespread use of certain digital practices.

The optimal criteria – reference points of "digital labor", in our opinion, were: "the number of people employed in the field of digital technologies in an enterprise (ICT specialists)", "the presence of centralized educational programs for workers in the field of digital technologies", "availability of ICT-related paid training courses for staff", "the presence of vacancies for ICT specialists that are difficult to fill", etc (table 3).

First, we address the key criteria for the usage of digital technologies in business processes. The visualization shows that medium and high-tech industries differ from low-tech ones by a higher level of cloud services use, emphasizing a certain level of the digital gap. The only exception here is the motor vehicles industry, where the intensity of use of cloud services is relatively low. A similar tendency is observed with the criterion of electronic commerce turnover, although there are more exceptions among medium and high-tech industries that are the chemical industry and the production of electrical equipment.

In the production of electrical equipment, the relative levels of the usage of digital devices and the Internet are the highest among medium and high-tech industries, although this industry is lagging behind in the exchange of information in digital form with consumers and contractors. In the production of machinery and equipment n. e. c., the most important criterion is electronic invoicing.

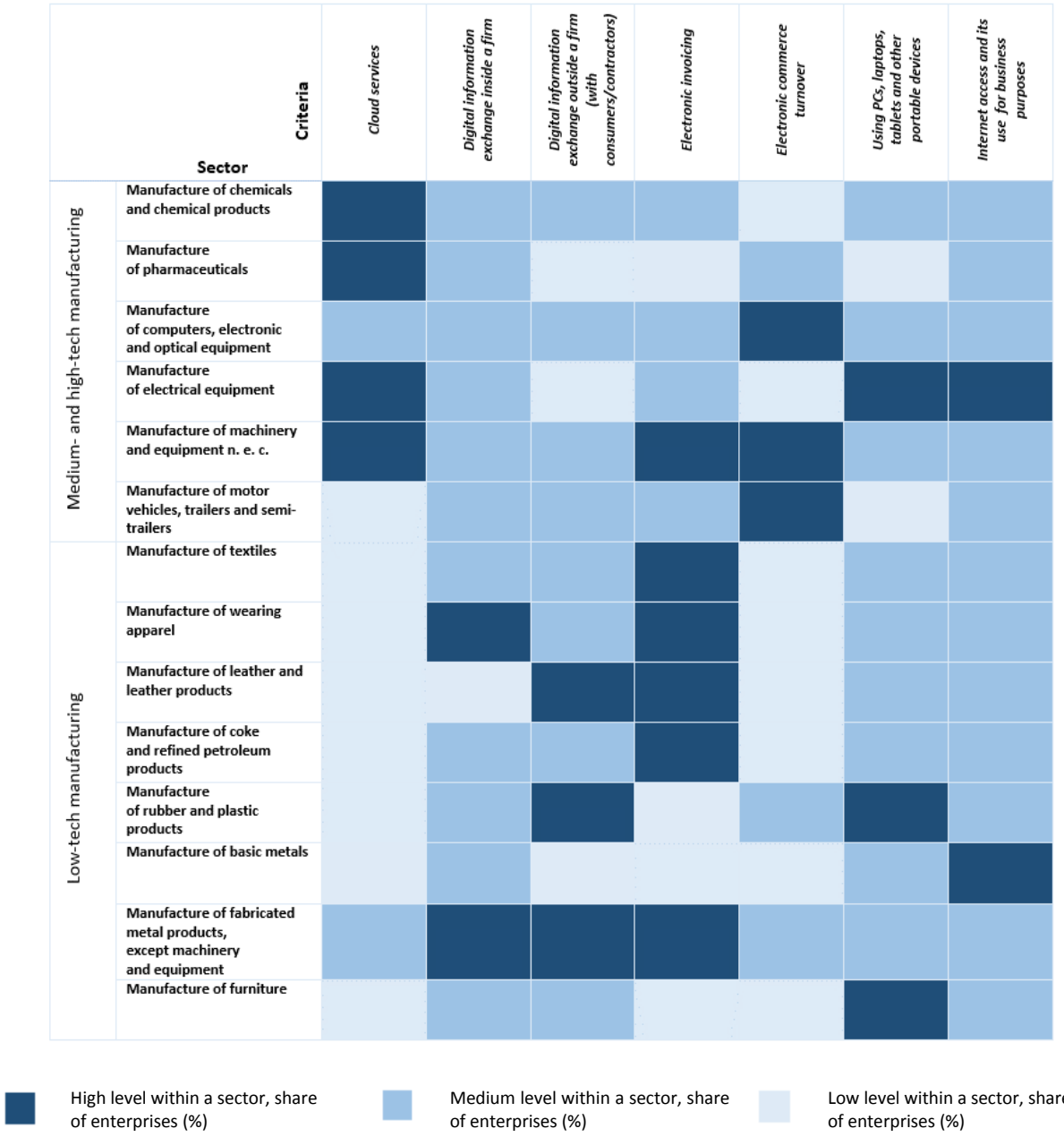
In the pharmaceutical industry, relatively less intensive use is demonstrated in such criteria as the exchange of information in digital form with consumers and contractors, electronic invoicing and the usage of digital devices.

Low-tech industries are primarily distinguished by the fact that, unlike medium- and high-tech industries, they are focused on the criterion of electronic invoicing. Such feature occurs in the production of textiles, wearing apparel, leather, coke and petroleum products and fabricated metal products. However, in the other low-tech industries this criterion shows a low level of intensity.

In addition, technological processes associated with the criterion of the exchange of information in digital form with consumers and contractors are important for the low-tech segment. By this criterion, a high intensity is demonstrated by the leather, rubber and plastic products and fabricated metal products industries.

In general, in both medium, high-tech and low-tech segments, the usage of digital technologies in business processes is fairly evenly distributed among various criteria, with the exception of those that show lagging behind for all industries of the particular segment.

Table 2 — Usage of digital technologies in business processes



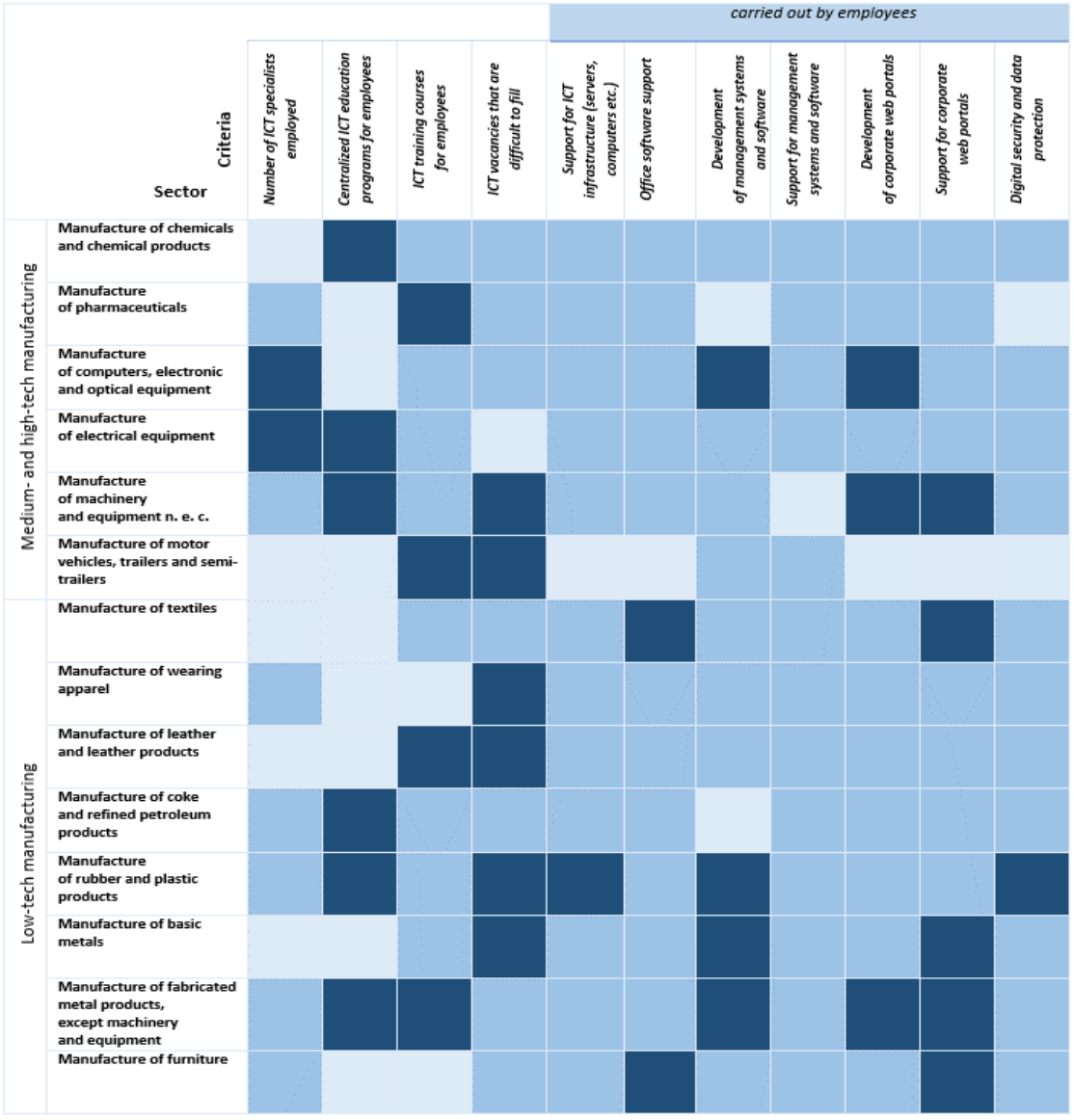
Let us move to the category of the "digital labor" now (table 3). Here there is a somewhat greater variation in the emphasis of criteria among the industries.

As expected, the manufacture of computers, electronic and optical equipment and the manufacture of electrical equipment became the leaders in the number of ICT specialists employed. By the development of centralized educational programs in the field of digital technologies, all sectors were divided between the two groups with a large gap between them: in the chemical production, the production of electrical equipment, machinery and equipment n. e. c., coke and refined petroleum products, rubber and plastic, and fabricated metal products, such programs were conducted with relatively high intensity, and in other industries – with a noticeably lower. At the same time, third-party ICT skills training courses receive attention at least at an average level in almost all industries, with the exception of the wearing apparel production and the furniture production, which means that employers understand the need to invest in digital human capital of their employees, at least at a basic level. In many industries, there is a shortage of ICT specialists to fill existing vacancies, which also demonstrates the

awareness of the need for digital transformation and employees with advanced knowledge in the field of digital technologies.

As for the implementation by the company's own employees of various functions in the field of digital technologies, the distribution is relatively even. In the computer industry, due to its specifics, there are more enterprises where their own employees are engaged in the development of software and corporate web portals. In the production of machinery and equipment n. e. c., according to the results obtained, the functions associated with the development and support of corporate web portals are also carried out by employees to a big extent. Of the individual industries, car manufacturing stands out here, where a significant number of criteria for the digitalization of labor indicate a lag. The motor vehicles industry stands out from the majority of other industries, having low levels for many digital labor criteria. Along with this, the criterion of the number of ICT specialists is low in the chemical production, basic metals, textiles and leather.

Table 3 —Digital Labor



6. Factors that impede digitalization

Considering that one of the main goals of monitoring digital activity was to identify industry-specific problems that hinder the process of digitalization of manufacturing in 2018, in the final section of the findings we focused on the results of the survey, which allowed us to determine which factors were among the main obstacles.

It should be emphasized that the formation of a business climate, the individual parameters of which are crucial for the digital potential, took place within a sluggishly low growth of the manufacturing industry with background stagnation, well below the world average. The weakness of investment and consumer demand, economic uncertainty and a number of other negative factors hindering the development of manufacturing business, amid the absence of accented factors that improve business conditions, adversely affected the dynamics of industry production. As a result, during the implementation of strategic initiatives related to the introduction and development of digital technologies, economic agents inevitably faced not only problems specific to this process, but also difficulties caused by external economic conditions.

The survey results on the manufacturing industry as a whole showed that the range of problems faced by enterprises is quite wide, but, according to 60% of managers, the lack of sufficient financial resources was the main obstacle to the spread of digital technologies. Serious obstacles include the still low readiness (adaptability) to the integration of digital transformations, which is characteristic of almost every third enterprise. The above two circumstances were aggravated by a third noticeable problem, consisting in the absence of a digital strategy in 30% of enterprises on the development agenda. Significant negative pressure on the digital growth of the Russian manufacturing industry was attributed by 27% of managers to the lack of favorable and stable economic conditions in the country, which also makes this factor one of the most frequently mentioned (*ISSEK, 2018*).

To determine the degree of significance of problems in medium and high-tech, as well as low-tech industries, we ranked the data on the share of enterprises in each industry whose managers mentioned the influence of a particular factor. A three-grade scale was used (for example, the factors that were most frequently mentioned by respondents were considered the most significant, appearing in the table as a dark blue circle). The results for the manufacturing industry, according to the differentiation based on the technological level, are presented in table 4.

In general, the analysis showed a more acute and more negative reaction to problems in the industries with the most dynamic progress in digital transformation. In particular, in a number of industries – in the manufacture of machinery and equipment n. e. c., the manufacture of finished metal products and the manufacture of rubber and plastic products – almost all factors are perceived quite strongly. They are followed by the production of electrical equipment, computer production, chemical production and basic metals production, where there are also a relatively large number of mentioned factors that impede digital transformation. In all other industries, respondents indicate only some individual factors. Probably, the decrease in negative assessments there is associated with a relatively low or complete lack of digitization processes.

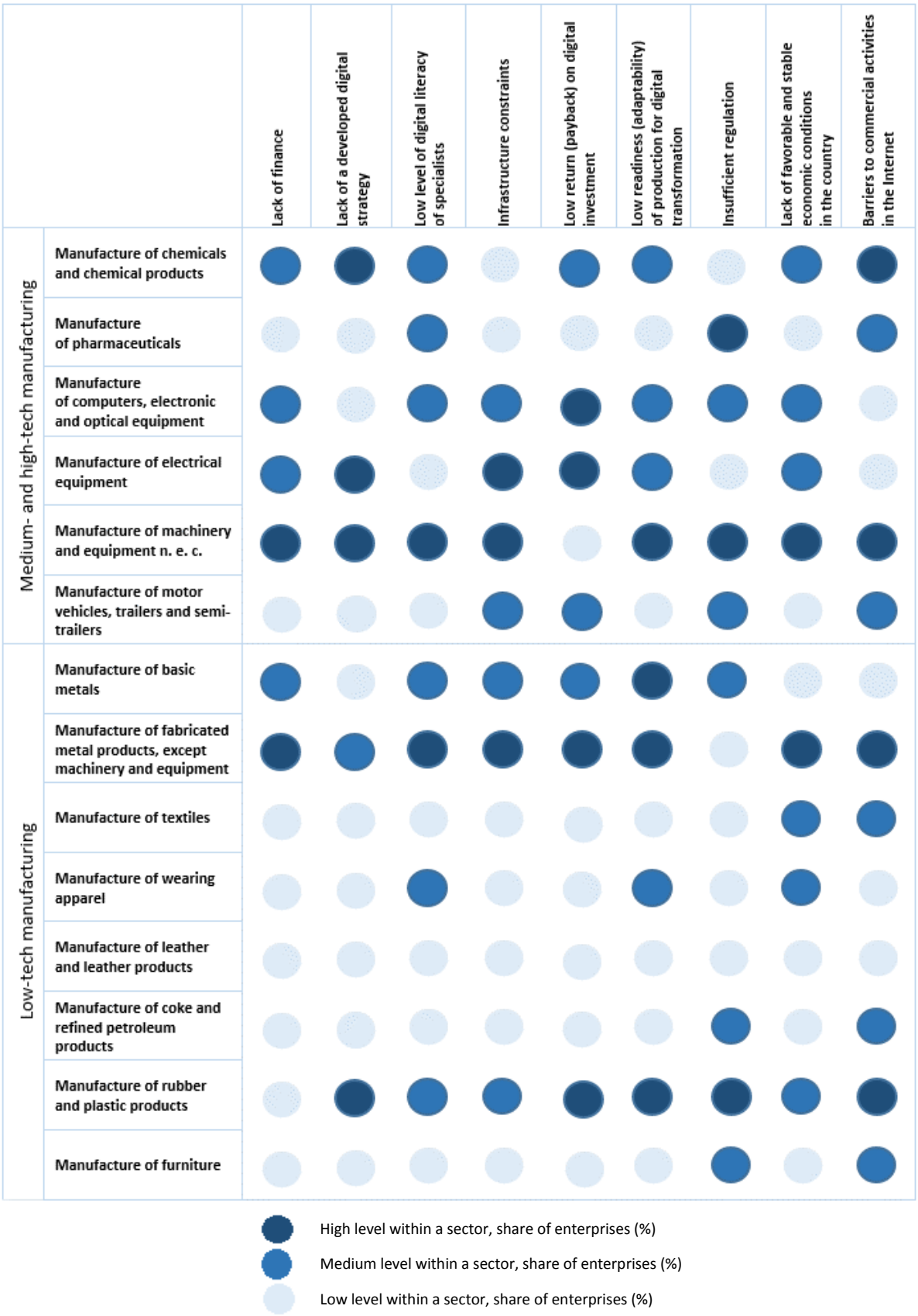
Let us consider in more detail the degree of significance of the individual factors influence. The lack of financial resources – as the most significant factor in the manufacturing industry as a whole – was perceived most strongly in the production of machinery and equipment n. e. c., finished metal products and relatively strongly in chemical production, computers, electrical equipment, basic metals, thereby uniting all industries with a more acute reaction to the problems, with the exception of the production of rubber and plastic products. Perception of the lack of a developed strategy as an important factor was less common in the industry context and clearly divided manufacturing into sectors where this problem was felt very strongly (chemical industry, production of electrical equipment, machinery and equipment n. e. c., rubber and plastic) and the rest with a weak level of perception, except for the production of finished metal products, where a negative reaction to the lack of a strategy was on the medium level.

Low readiness of production for digital transformation is often mentioned as an important obstacle in the industry context of entire manufacturing, being especially significant for the manufacture of basic metals, fabricated metal products, rubber and plastic products, machinery and equipment n. e. c. The lack of favorable and stable conditions in the country was a problem, which caused the negative reaction at a strong level only in the production of machinery and equipment n. e. c. and fabricated metal products, but at the medium level this problem was perceived in many industries, including low-tech production of textiles and wearing apparel.

The factor associated with the low return on investment is not perceived at the high level, unlike other problems, in the production of machinery and equipment n. e. c., which is another evidence of the industry's high readiness for digital transformation. At the same time, for the production of computers, a low return on investment had become an important obstacle to digital transformation.

The only factor that turned out to be relatively insignificant for the production of fabricated metal products was associated with regulation. Nevertheless, insufficient regulation caused a high-level negative reaction in the manufacture of pharmaceuticals. In general, the profile of obstacles for pharmaceuticals differs largely from other industries: in addition to insufficient regulation, the lack of digital literacy of specialists and barriers to commercial activities in the Internet became the most significant for pharmaceuticals compared to other factors.

Table 4 — Distribution of factors that impede digitalization by their importance



Conclusion

Defining digital transformations primarily in manufacturing activities as a strategic imperative for the entire economy, the paper presents and analyzes the results of conjuncture monitoring, which characterize important industry tendencies and phenomena occurring as part of digital transformation of manufacturing. Our work is the first step in the study of entrepreneurial assessments of tendencies in the digital economy. Reliable measurements of the effects of such economic phenomena have not yet been conducted in the country. The results of the conjuncture monitoring undoubtedly improve the quality of information flows on the positive economic impact of digitalization. As a result, the novelty of the study in terms of completing the gaps in statistical information about economic events and tendencies related to the spread and growth rate of industry digitalization consisted of generalized assessments of opinions and intentions of entrepreneurs regarding the introduction of breakthrough business models and digital technologies in manufacturing enterprises.

In general, the survey revealed significant differences in entrepreneurial judgments regarding most aspects of digitalization of production. This tendency emphasizes the multi-structural nature of the Russian manufacturing industry, when its various segments operate in fundamentally different economic conditions, primarily in terms of access to development resources, and, accordingly, have fundamentally different potential for digital development. However, on the other hand, despite the fact that the transition to Industry 4.0 takes place within the relatively unfavorable business climate, the obtained opinions allow us to state that the level of immersion of the manufacturing enterprises into digitalization processes is not yet deep, but the progress is obvious. Interest in Industry 4.0 is gradually being transformed into concrete investments and real results, contributing to the ever-increasing growth of the level of digitalization and integration in large and medium-sized industrial enterprises. This is largely manifested in the identified tendencies of digital preferences, the level of prevalence (presence) of technologies in each of the studied industries, preferences in the field of planned digital technologies and the expected benefits from investments.

The most important features should be considered the following:

— the digital agenda was a sufficient priority in the industrial development of the studied set of enterprises in 2018, but many technologies were still under development, requiring serious investments and improvements;

— the observed differences in the opinions of the management of manufacturing enterprises are fairly objective and indicate a significant level of heterogeneity in the development of certain types of activity in manufacturing enterprises;

— IIoT, intellectual robotic complexes and manufacturing analytics are most common in the medium and high-tech segment; 3D printing technologies and RFID tags are presented at different levels of distribution in a large number of industries, which may indicate an active dynamics of their introduction and development in Russian manufacturing;

— among the targets of using 3D printing, the most common was the creation of prototypes and models for internal use, although in some industries the use of 3D printing for the production of details and parts of goods for sale was developed;

— as part of the planned to introduce technologies, 3D printing technology, together with additive technologies, had become the most popular in the middle and high-tech segment; in the low-tech segment, such technologies were 100% utilization and recycling, end-to-end automation, as well as 3D printing, which also become important for a number of industries;

— the use of cloud services had become one of the main markers for the high intensity of the use of digital technologies in business processes in the mid- and high-tech segment, while in the low-technology segment it was electronic invoicing;

— the issue of labor digitalization had received considerable attention in the vast majority of manufacturing industries. Many enterprises in various industries invest in the

organization of educational programs and pay for training courses in the field of IT for their employees.

We can try to trace further ways to address the problem. One of them is associated with the further expansion of the conjuncture observation program and subsequent analysis: the inclusion of other industries outside manufacturing, the study of new digital technologies and new forms of digital activity.

Of course, the next important step is the development of composite indicators. Such indicators may be, for example, a digital transformation indicator, compiled on the basis of entrepreneurial assessments of the level of digital technologies and practices of the digital economy prevalence; a labor digitalization indicator based on relevant criteria; an indicator of digital investment activity, etc.

Another possible direction of research can be an in-depth cross-analysis of the relationship between the economic performance of enterprises, such as profit or labor productivity, and generalized assessments of their managers regarding the digitalization of their own production. This kind of research can be conducted in a sectoral context too. The results of such a study will allow a better estimation of the economic effect of digital transformation through the use of alternative indicators from conjuncture surveys.

In addition, conjuncture monitoring can be used to predict the pace and quality characteristics of digital transformation in the framework of foresight research. Several studies can be devoted to analyzing the effectiveness of using the composite digitalization indicators to predict various economic and technological quantitative indicators.

Acknowledgements

The article was prepared within the framework of the Basic Research Program at the National Research University Higher School of Economics (HSE) and supported within the framework of a subsidy by the Russian Academic Excellence Project '5-100'.

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