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**INDICATORS FOR MEASURING  
THE DIGITAL ENVIRONMENT OF  
MANUFACTURING ENTERPRISES  
IN RUSSIA BASED ON DATA  
FROM BUSINESS TENDENCY  
SURVEYS**

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## **INDICATORS FOR MEASURING THE DIGITAL ENVIRONMENT OF MANUFACTURING ENTERPRISES IN RUSSIA BASED ON DATA FROM BUSINESS TENDENCY SURVEYS**

The paper discusses various aspects of digital environment and activity of enterprises from the Russian manufacturing sector in 2020 using the evidence from business tendency surveys. Based on aggregate sectoral and industrial assessments, such as the Digital Climate Index (DCI), the Digital Intensity Index (DII), the Digital Employment Index (DEI) and the Digital Vulnerability index (DVI), the dynamics of digital development during the COVID-19 crisis in 2020 is described. In general, according to the results obtained, we can conclude that, despite all the negative consequences and uncertainty associated, 2020 became a very significant point in terms of the digital transformation in manufacturing. Manufacturing businesses were both relatively resilient to the adverse business trends caused by the pandemic and were able to absorb the positive digital momentum generated by the pandemic.

Keywords: digital technology, COVID-19, business tendency surveys, manufacturing, Russia.

JEL: D22, J21, J24, L21, L60, M12, M15, O14, O33.

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## Introduction

The crisis triggered by the worldwide COVID-19 pandemic marked a turning point in history in terms of its impact on human life, comparable to large-scale economic crises and wars. Measures taken to combat the pandemic, such as quarantine and physical distancing, have led to the forced transfer of many forms of human activity and interaction from offline to online environment, which, as can be assumed, is a potential factor in the rapid development of digital technologies in sectors of the economy affected by these restrictions.

The most studied aspect of technological transformation in the context of a pandemic in the literature at the moment is the development of digital technologies used in the medical and sanitary spheres (Golinelli et al., 2020; Budd et al., 2020), although the study of transformations in a broader context is also gaining attention (Vargo et al., 2021). Overall, the available evidence points to a particularly widespread development of computed tomography, video-based communication platforms and artificial intelligence in healthcare, education, work and everyday life. In the United States, during the pandemic, the number of patents significantly rose in the field of video conferencing, telecommuting, and work from home (Bloom et al., 2021).

Nevertheless, our knowledge about the digitalization of the entire economy or its large segments as a whole is still rather insufficient; fragmentary evidence prevails only from certain fields of activity. Has the pandemic catalyzed a digital surge across the whole economy or remained visible only in certain areas? Has it caused the digital divide to deepen? Whereas in industries such as health care and education, which have become most susceptible to imposed restrictions, predicting the cumulative effect may be a feasible task, in less obvious cases, such as manufacturing, it is much more difficult. Certain manufacturing industries, such as pharmaceuticals, were clearly more affected by the pandemic than others were. Available global evidence suggests that COVID-19 has dramatically accelerated the digital transformation of the pharmaceutical industry, with technologies such as cloud computing and cybersecurity helping the industry move to remote work and conduct decentralized clinical trials (Pharmaceutical Technology, 2021).

Despite the positive potential of the imposed restrictions in terms of digital development, the pandemic has proven to be a major negative economic shock. For example, early data from Russian surveys of business activity in key sectors of the Russian economy conducted by Federal State Statistics Service (Rosstat) during 2020 showed the most significant contraction for at least the last ten years of observations. According to OECD (2020), the shock of COVID-19 has

negatively impacted venture and seed investment, a key source of funding for innovative start-ups. However, the negative impact on investment was weaker than during the 2001-02 dot-com crisis and the global financial crisis of 2008-09 (Gompers et al., 2020). The negative impact on digital innovation could also be expressed in changing management priorities towards tasks related to current anti-crisis activities to the detriment of long-term digital initiatives and projects (McKinsey, 2020; BMWi, 2020).

Thus, the cumulative effect of the pandemic on digital development in the manufacturing sector is not entirely clear; it is likely that in different industries and in different conditions, it could vary greatly, depending on whether positive or negative factors were more significant. For example, this difference is reflected in OECD (2021a) data on a number of selected R&D-intensive companies, according to which R&D investments in IT and pharmaceuticals increased in 2020 compared to the previous year, while investments in the automotive, aerospace and defense sectors declined.

In this situation, statistical studies based on large representative data are needed to assess current digital trends without strong distortions. For instance, OECD (2021b), Eurostat (2021), United Nations (2021) and others are engaged in such programs. Although they are based predominantly on quantitative statistics; semantic citation rate meters are also gaining popularity (see, for example, the “digital pulse” measure). Quantitative indicators are often used as building blocks for digital development indices, such the International Digital Economy and Society Index (I-DESI) (European Union, 2021), as the Networked Readiness Index (NRI) (Portulans Institute, 2020), Digital Business Indicators (World Bank, 2019), The IMD World Digital Competitiveness Ranking (IMD, 2018).

Among the existing meters, two important problems can be distinguished that can become especially noticeable when trying to study the digital effects of a pandemic. First, the indices used often focus on universal assessments of the digitalization of economy and society, while underestimating the role of industry digitalization factors. For a more nuanced assessment, a larger number of indicators may be required. For example, Tolkachev (2020) proposes the Index of Digitalization of Manufacturing Enterprises, which consists of two sub-indices - the Cyber-Physical Systems Development Index and the Business Model Transformation Index, which are based on OECD data, to assess the state of digital development in the manufacturing industry only. In addition to the industry aspect, we can highlight various aspects of digital development, which can also be considered separately for a more detailed understanding of trends (for example, separation by enterprise size).

Secondly, despite the presence of many digital meters and indicators, the difficulty is in the lack of a common methodological standard, which additionally leads to differences in existing estimates. Nevertheless, the program for measuring the digital economy developed in the European Union is a good example of a solid methodological basis, which can serve as a model for the development and harmonization of existing practices (Eurostat, 2020).

In particular, on the basis of this program, CBTS ISSEK NRU HSE has developed a methodology for measuring the digital environment in the basic segments of the Russian economy, such as manufacturing, trade and information technology, since 2018<sup>5</sup>. As part of the launched annually updated business tendency observations, an analysis of the dynamics of indicators of digital transformations at enterprises and organizations throughout the country is carried out in this paper.

The transformations that have taken place have increased the demand for the prompt identification of new vectors in the evolution of the digital development of the Russian manufacturing industry. Given the unprecedented challenges of 2020 and still insufficient content of timely statistical data capable of reflecting the scale of digitalization in an expanded and relevant form, the results of qualitative business surveys, in addition to quantitative estimates, become an important complementary source of information, which, among other things, allows drawing conclusions not only about the actual the reaction of enterprises to the coronavirus dynamics due to the inclusion of the relevant blocks of questions in the survey instruments, but also to simulate the post-crisis business and digital environment in the short and medium run on the basis of the obtained short-term forecast estimates of the phenomena under study.

The aim of this work is to attempt a deep detailed analysis of the key aspects of the digitalization of the manufacturing industry and its low-, medium and high-tech industries in the context of severe pandemic-related negative dynamics by means of an expanded system of simple and composite digital business tendency indicators, harmonized with the methodology for measuring the digital economy and calculating indices developed by the European Commission.

The analysis of the state of the digital climate was carried out based on an expanded system of simple and composite indicators, including such new statistical tools as the *Digital Intensity Index (DII)*, the *Digital Climate Index (DCI)*, *Digital Employment Index (DEI)* and *Digital Vulnerability Index (DVI)*. The updated measurement system transmits with its dynamics aggregate trends of business, digital and investment activity, as well as the demand and intensity

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<sup>5</sup> <https://www.hse.ru/monitoring/buscl>

of technological transformation, reveals the peculiarities of employment at enterprises, including in terms of the intensity of attracting specialists with high competencies in the ICT field, and also allows to obtain unique aggregated assessments of measuring industry vulnerability to the effects of the coronavirus crisis, to show the degree of readiness of industries for digitalization in the face of a market shock.

The relevance of this goal seems undeniable, since future digital trends are directly related to what the transformation will be like now. Our assessments made using the proposed tools will be the first such results on a national scale. Given the complexity of the nature of digital effects demonstrated above, we focus on a high level of detail, separately considering different sub-sectors of the manufacturing industry and various aspects of digital development through assessments of the indicators involved.

## **Data and Methodology**

The empirical basis for this study was the results of the annual pilot business tendency surveys program “Digital Activity of Manufacturing Enterprises”, which has been conducted since 2018 at the request of CBTS ISSEK NRU HSE in order to measure the dynamics and analyze trends of the key components of the digital transformation process. Surveys are carried out within the framework of a specially developed questionnaire, “Survey of Business Tendencies and Digital Activity of Manufacturing”, which is subject to regular updating. The questionnaires are filled in by respondents (directors or managers of organizations) with the necessary level of competence in relation to the questions asked at the end of the second half of the surveyed period.

The key features of the information obtained in the course of business tendency surveys include the fact that this information describes the perception of the observed trends and not changes in objective conditions, as well as the qualitative nature of answers collected and the relative promptness of obtaining in comparison with quantitative statistics data. In general, the system of indicators and the structure of the corresponding questions in the survey program is based on the following standard methodological principles arising from the recommendations of the Organization for Economic Cooperation and Development and the Statistical Department of the European Commission (OECD, 2003): questions refer to the characteristics of the activities of the directly surveyed organization; the questions reflect the dynamics of indicators for the current year and their change in relation to the previous period; for all issues related to assessments of the dynamics (trends) of indicators, a three-category grading is used: the number of respondents who note an increase (improvement) (+), no changes (=), a decline (deterioration) (-), respectively.

The developed survey instruments are harmonized with European practice of measurements of digitalization processes. The key criteria of the survey methodology are the unification of sectoral survey programs, the homogeneity and significance of target groups of respondents, the ability to determine homogeneous sample sets and their stratifications according to established types of activity, unity with well-known international standards and recommendations, allowing cross-country comparisons.

The questionnaire used in the surveys is adapted to the Russian context of digital transformation, which causes a number of discrepancies in the questions compared to the European community's questionnaire on the use of ICT and e-commerce in enterprises, as well as the presence of additional questions and blocks. At the same time, as mentioned above, our questionnaire is based on the methodological principles set by European practice, and is generally consistent with the thematic structure characteristic of the European questionnaire. In particular, the following correspondence can be established between the thematic blocks of the questionnaire of the European community on the use of ICT and e-commerce in enterprises and the instruments of our survey: block A "Access and use of the internet" of the European questionnaire corresponds to questions 2.4 and 8.7 of our questionnaire; block B "E-commerce" corresponds to question 2.12; block C "Invoicing" corresponds to question 2.9; Block D "Use of cloud computing services" corresponds to questions 2.6 and 10.7; Block E "Big data analysis" corresponds to questions 10.1, 10.17 and 10.18; block F "ICT specialists and skills" corresponds to question 2.3, block of questions 5 and question 8.4; block G "Internet of Things" corresponds to questions 10.5, 10.6, 10.13; block H "Use of 3D printing technologies" corresponds to block of questions 7, questions 10.4 and 10.12; Block I "Use of robotics" corresponds to questions 4.11, 10.2 and 10.3.

In 2020, the third round of the observation was carried out, within which, for the first time on a national scale, the results of a survey were presented, reflecting detailed assessments of business leaders regarding the impact of COVID-19 on the dynamics of business, digital, employment and investment activity. Additional blocks of questions were included in the survey questionnaire of the 2020 Observation Program, which made it possible to expand the understanding of the effects of the cumulative shock of the coronavirus crisis on various aspects of the sectoral activities related to the technological transformation process. In particular, the survey questionnaire was updated and included special "crisis" questions, which made it possible to identify direct assessments of the digital effects of the pandemic directly by the respondents themselves.

The total sample consists of 1150 large and medium-sized enterprises registered in Russia, included in section C of the OKVED-2 classification. The sample is representative for all units of observation, multidimensional, stratified, and representative for the main economic parameters of thirty regions of Russia<sup>6</sup>. Taking into account the likely differentiation in the responses of various segments of the manufacturing industry to the COVID-19 crisis, we often differentiated between various types of activities within manufacturing, which is possible due to the possibility of detailing the results to the second level of OKVED-2 classification. In many cases, these sub-sectors were united into groups in terms of the level of technological advancement of production.

The distribution of activities into medium- and high-tech, as well as low-tech activities was carried out in accordance with the recommendations of UNIDO<sup>7</sup>. It is based on the International Standard Industrial Classification (ISIC) and the Standard International Trade Classification (SITC), as well as a version of the OECD classification adapted to the characteristics of the countries of the post-Soviet region, which links industry spending on research and development with sizes of value added and production.

The processing of raw materials is made up of activities mainly with a low level of technology, labor-intensive production processes and low capital intensity. The possible competitive advantages of such industries are determined mainly 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. This group of industries is not considered in our study.

Low-tech industries include industries that have fairly simple requirements for the skills and qualifications of workers, 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 remain within the country.

Medium-tech and high-tech manufacturing industries for Russia are combined, according to UNIDO recommendations, into one group, characterized by complex technologies and high requirements for personnel qualifications. Mid-tech industries combine manufacturing with moderately high levels of research and development, requiring sophisticated skills and long-term learning. High-tech industries use advanced technologies that require high investments in research

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<sup>6</sup> Krasnodarskij kraj, Krasnojarskij kraj, Primorskij kraj, Stavropol'skij kraj, Habarovskij kraj, Arhangel'skaja oblast', Vladimirskaja oblast', Volgogradskaja oblast', Vologodskaja oblast', Nizhegorodskaja oblast', Irkutskaja oblast', Tverskaja oblast', Kemerovskaja oblast', Samarskaja oblast', Sankt-Peterburg, Leningradskaja oblast', Moskva, Moskovskaja oblast', Novosibirskaja oblast', Rostovskaja oblast', Sverdlovskaja oblast', Smolenskaja oblast', Tul'skaja oblast', Tjumenskaja oblast', Cheljabinskaja oblast', Respublika Bashkortostan, Respublika Dagestan, Respublika Tatarstan, Udmurtskaja Respublika, Respublika Saha.

<sup>7</sup> UNIDO. Classification of manufacturing sectors by technological intensity (ISIC Revision 4). URL: <https://stat.unido.org/content/learning-center/classification-of-manufacturing-sectors-by-technological-intensity-%28isic-revision-4%29;jsessionid=B99E902A3918AB9F3DF9859923DFC4F4>



and development, advanced technological infrastructure and a high level of specialized technical skills.

Table 1 shows the classification of the types of economic activities of the manufacturing industry in accordance with the nomenclature from the OKVED-2 classifier, as well as the short names used for their designation purpose hereinafter.

*Table 1.* Classification of types of economic activities of the manufacturing sector by the level of technological development in accordance with the all-Russian classifier of types of economic activities OKVED-2 (2017-2018)<sup>8</sup>

<b>Medium and high-tech production</b>		<b>Low-tech production</b>	
20	Manufacture of chemicals and chemical products [«CH»]	13	Manufacture of textiles [«T»]
21	Manufacture of medicines and materials used for medical purposes [«MD»]	14	Manufacture of wearing apparel [«W»]
26	Manufacture of computers, electronic and optical products [«C»]	15	Manufacture of leather and leather products [«L»]
27	Manufacture of electrical equipment [«E»]	19	Manufacture of coke and petroleum products [«CP»]
28	Manufacture of machinery and equipment not included in other categories [«ME»]	22	Manufacture of rubber and plastic products [«RP»]
29	Manufacture of motor vehicles, trailers and semi-trailers [«MV»]	24	Metallurgical production [«MT»]
		25	Manufacture of finished metal products, except for machinery and equipment [«FM»]
		31	Furniture manufacture [«F»]

## Instruments of measurement

Along with simple indicators that point out trends, it is advisable to use aggregated values to assess the overall scale of the phenomenon in dynamics. Such meters are actively used, on the basis of various methodological principles, including the widespread and most relevant method of principal components for working with nonparametric information, as well as the expert distribution of the weights of indicators.

This work also applies this approach when constructing the following composite indices: *Digital Climate Index (DCI)*; *Digital Employment Index (DEI)*; *Digital Vulnerability Index (DVI)*; *Digital Intensity Index (DII)*. This work focuses on identifying common key tendencies within the consequences of the pandemic, and not the use of individual digital technologies, such as 3D printing or the Internet of Things, therefore, aggregated estimates are crucial for us.

Let us consider in more detail the methodological principles of constructing these tools. When choosing a methodology for constructing the composite aggregates, priority was given to

<sup>8</sup> All-Russian Classifier of Economic Activities ver. 2. URL: [http://www.consultant.ru/document/cons\\_doc\\_LAW\\_163320/](http://www.consultant.ru/document/cons_doc_LAW_163320/).

the methods on which the indices built by the European Commission based in the framework of monitoring digital transformation, such as the European Digital Intensity Index (DII) and Digital Technology Integration Index (DTII), due to the possibility of their maximum harmonization with the European practice of measuring digital activity.

The first three indices are calculated using the principal component analysis, aggregating the estimates of changes in the relevant parameters of the digital environment similar to the European Digital Transformation Integration Index (DTII). The DCI measures the aggregate digital sentiment in the manufacturing industry by aggregating estimates of changes in key parameters of the digital environment: digital activity, investment in technology, demand for digital products. DEI measures changes at enterprises in terms of the dynamics of the number of employment of specialists with ICT competencies. In addition to the DEI, the Total Employment Index (TEI) is involved in the work, which makes it possible to track the dynamics and trends regarding all the employees at the enterprise, and not only specialized in the field of ICT. DVI measures the general level of vulnerability (stress resistance) of enterprises to the typical industrial limiting barriers for development, as well as to sudden shocks of the business and digital environment.

The methodology for constructing the ICT is a version of the methodology for calculating the DII (Digital Intensity Index) developed by Eurostat (2020), adapted for Russia, calculated on the basis of the results of the annual European survey on the use of ICT and e-commerce in enterprises. Original DII is a 12-point micro-index that is calculated for each individual enterprise from the sample population. Each enterprise can score from 0 to 12 points, depending on how many criteria of digital intensity it satisfies. Enterprises are then divided into four groups of digital intensity: very low (score 0-3), low (score 4-6), high (score 7-9), very high (score 10-12).

The set of criteria used by Eurostat is revised and adapted every year to better suit the changing realities and the current stage of digital development, but the general idea remains the same: the index is intended to reflect the depth of the enterprise's involvement in digital transformation in terms of its various aspects. Accordingly, the list of criteria has evolved over time and included, among others, the following: Internet use by the majority of employees; access to ICT specialists; access to fixed broadband speed higher than 30 Mbps; mobile devices are used by more than 20% of employees; presence of a company website; presence of a company in social networks; electronic sales are at least 1% of the total turnover; presence of B2C sales via the Internet; electronic exchange of information on supply chain management; purchase of services in the field of cloud computing; sending electronic invoices.

In this work, the methodology was adapted in the form of a similar but 9-point micro-index. Most of our criteria are identical to those used to construct the European counterpart index; some of the criteria, in which case it was impossible to find complete analogs among the indicators of the questionnaire, was replaced by other indicators that were close and relevant in meaning. For some of the criteria, it was not possible to find adequate analogues, which led to a decrease in the total number of calculated points from 12 to 9. Similarly, enterprises were divided into four groups of digital intensity level according to a slightly different classification: low (score 0-2), medium (score 3- 5), above average (score 6-7), high (score 8-9).

A distinctive feature of the Russian index in comparison with the European one is that this index is tied to entrepreneurial assessments of current tendencies. Compliance with the index criterion in the case of Russian business tendency survey-based index means that, from the respondent's point of view, during the year when the survey was carried out, the company underwent positive changes in the considered parameter of digital intensity. Accordingly, our index primarily reflects the situation “in almost real mode of time”, i. e., the current dynamics of industry changes. This point of view is especially convenient for analyzing industry events that took place in 2020 in connection with the onset of the coronavirus crisis.

Thus, calculated for the 2019 and 2020 survey results, DII was based on the following 9 most relevant criteria (indicators), characterized by a growth trend in the current year compared to the previous year, which we selected from observations:

- 1) The use of personal computers, laptop computers, tablets and other portable devices in the enterprise;
- 2) The number of employees in the field of digital technologies at the enterprise (ICT specialists);
- 3) Internet access and use of the Internet for business purposes;
- 4) Use of own website;
- 5) Use of cloud services;
- 6) Exchange of information in electronic form at the enterprise;
- 7) Exchange of information in electronic form on supply chain management with other enterprises, suppliers or consumers;
- 8) Electronic invoicing;

9) The presence of the enterprise in social media.

As the European research practice shows, DII is good at identifying differentiation between countries and sectors of the economy in terms of digitalization. The European experience shows that the most digitalized sector is the ICT sector in the broadest sense, as well as a number of segments of the service sector, including wholesale trade. The manufacturing industry is not a leader: on average, only about 10-15% of enterprises could be classified as enterprises with high digital intensity according to the European index.

## **Results**

### ***1. Digital Climate Assessments***

The sudden shock caused by COVID-19 did not severely distort the digital climate in the manufacturing industry but given the unprecedentedness of the calls that have shifted production to a mode of increased mobilization, the focus on digitalization has decreased in some of them. The results of the 2020 survey indicate moderately negative consequences of the pandemic for the manufacturing segment as a whole, but rather asymmetric manifestations of the crisis in sub-sectors, including those that received a stimulating impetus.

The change in DCI in 2020 compared to 2019 allows us to conclude that the segment as a whole avoided a sharp break in the dynamics of the digitalization process, demonstrating only a slight slowdown in the intensity of its individual components: the indicator dropped to 99.6 from 99.8%, having lost only 0.2% (fig. 1).

At the same time, in the sectoral context, one can observe an increased volatility of the DCI values and, as a result, heterogeneity in the landscape of the digital environment, which indicates not only the unequal actual impact of the pandemic, but the individual specificity and role of digital solutions for production as a potential source of business growth, the competitiveness of products, and finally, as a tool for eliminating the consequences of the coronavirus crisis, which determined the high uncertainty of subsequent development.

Among medium- and high-tech enterprises, the deterioration of the digital climate was insignificant and, despite the weakening of positive trends in its estimates, most of them remained in the favorable range of the index values. In particular, the adjustment, which caused a slowdown in the growth of DCI, occurred at the chemical industry enterprises (the index decreased by 0.7% to 100.5%), as well as in the production of motor vehicles (by 0.9% to 100.5%).

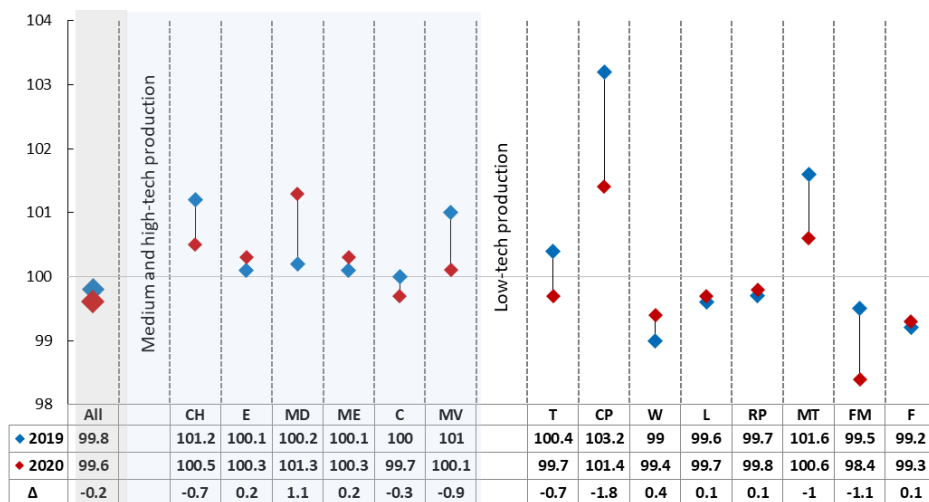
Among the low-tech industries, the most affected were enterprises producing finished metal products, except for machinery and equipment (a decrease in the DCI by 1.1% to 98.4%)

and textiles (a decrease in the DCI by 0.7% to 99.7%). A slowdown in the positive dynamics of the digital climate was noted at enterprises for the production of coke and petroleum products (a decrease in the DCI by 1.8% to 101.4%), as well as metallurgy (by 1% to 100.6%).

An improvement in the digital climate took place at enterprises producing electrical equipment, machinery and equipment (an increase in DCI by 0.2% to 100.3%, respectively). At the same time, among the low-tech industries, some leveling of unfavorable trends was shown by enterprises for the production of wearing apparel (DCI positively adjusted by 0.4% to 99.4%), leather and leather goods (by 0.1% to 99.7%), rubber and plastic products (by 0.1% to 99.8%), as well as furniture (by 0.1% to 99.3%).

Special attention should be paid to the change in the dynamics of the DCI, which aggregates a set of assessments characterizing digital activity, the demand for the use of digital products and investment in technologies at enterprises for the production of medicines and materials used for medical purposes. Compared to 2019, the index immediately increased by 1.1% to 101.3%, setting an absolute record in terms of the intensity of positive renewal among all the industries studied.

Fig. 1. Index of digital climate (%)



Source: authors' calculations

Note: In Fig. 1 and all subsequent ones, gray background corresponds to the manufacturing industry as a whole; blue background relates to medium- and high-tech industries; green one relates to low-tech industries. Below are the transcripts of the abbreviations for the names of the subsectors, which will be used in all further figures.

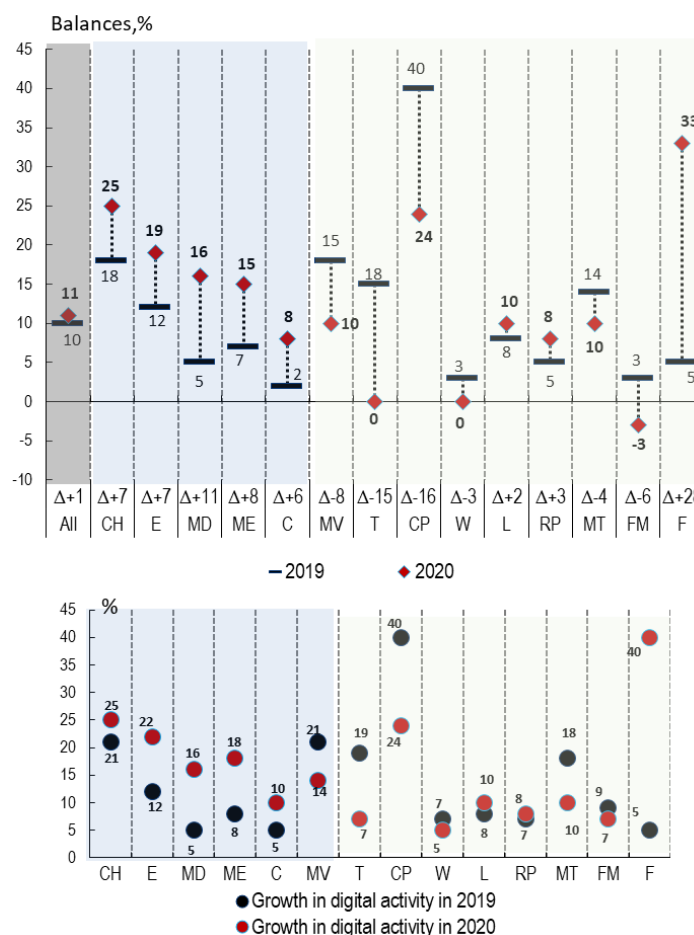
The leveling of the crisis component in the dynamics of the DCI was partly ensured by all three components of the index, however, the main “protection” against subsidence and the greatest contribution to the result was made by the indicators “digital activity” and “demand for the use of digital products”.

In particular, the processing segment in response to the pandemic maintained the trend of growth in digital activity and supported the pace recorded by the results of two previous pilot

observations during 2018 and 2019: the balance value of the indicator increased to the mark (+ 11%). Thus, according to the survey, 2020 was no exception - the updated result signals the high importance of digital processes, despite all features of the current moment and future uncertainty of the COVID-19 crisis.

Analysis of the dynamics of digital activity in the context of various activities within manufacturing industry shows an increase in its intensity compared to 2019 at all enterprises of the group of medium- and high-tech industries. Against this background, low-tech industries were characterized by a less pronounced positive adjustment, which was recorded only at enterprises producing leather and leather goods, rubber and plastic products, and furniture (Fig. 2).

Fig. 2. Assessments of digital activity



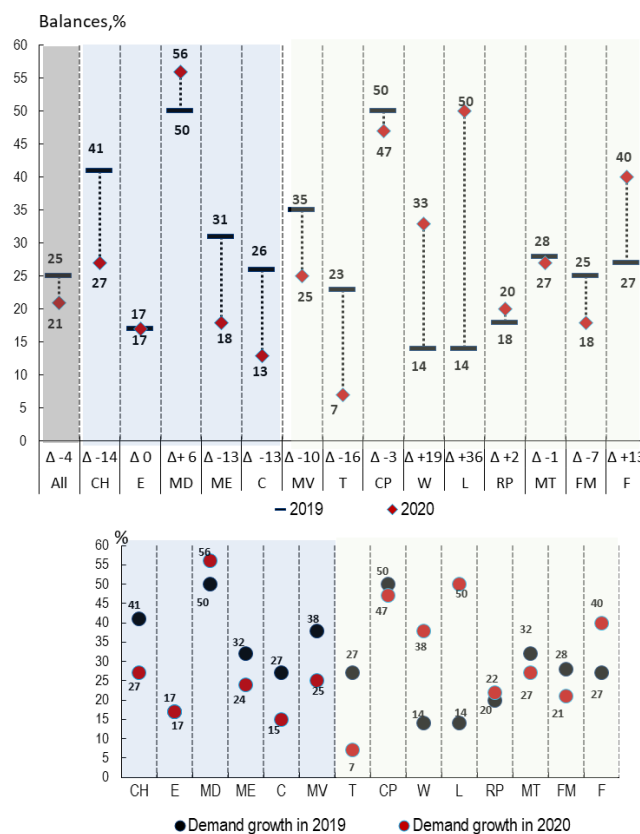
Source: authors' calculations

Of interest are the updated estimates of the next component of the DCI – “the demand for the use of digital products”, which, despite a slight decrease relative to 2019, maintained a high growth rate. According to the survey results, the balance value of the indicator was characterized by some weakening of the growth rate and amounted to (+ 21%) in 2020 against (+ 25%) in the previous year. Nevertheless, almost a quarter (23%) of managers continued to note an increase in the need to use digital technologies in production, while only 2% stated its decrease.

As the industry segmentation shows, in all of the studied types of activity, the dynamics of this indicator remained positive. An increase in the demand for the use of digital products compared to 2019 was recorded at enterprises for the production of medicines and materials used for medical purposes (in 2020, an increase of 56% in enterprises against 50%), wearing apparel (38 against 14%), leather and leather products (50 versus 14%), furniture (40 versus 27%), rubber and plastic products (20 versus 18%).

The most accentuated decline in demand for digital products was noted at enterprises producing machinery and equipment (growth continued by 24 against 32% of enterprises), computers, electronic and optical products (15 versus 27%), textiles (7 versus 27%), motor vehicles (25% versus 35%), as well as in chemical industries (27 against 41%).

Fig. 3. Estimates of the demand for the use of digital products



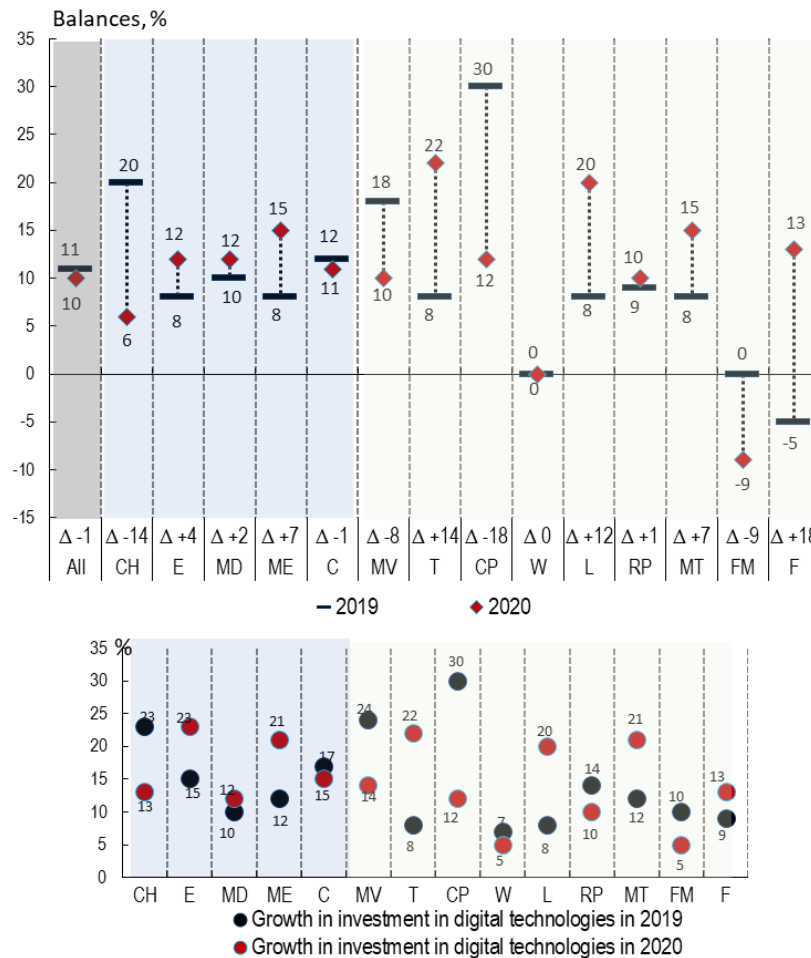
Source: authors' calculations

The contribution of the third component, “investments in digital technologies”, to the dynamics of the overall state of the digital climate turned out to be somewhat less significant but it can help to analyze changes in the digital sentiments of respondents through the prism of financial asymmetries that have arisen in the digitalization process.

In general, the dynamics of investment in technological development in the updated business environment retained a high inertia in 2019, during which, according to the survey, the increase in investment spending accelerated relative to 2018. In 2020, the growth trend in

investment in digital products slowed down but did not lead to significant imbalance – the balance of the assessment of the change in the indicator decreased by 1 percentage point up to (+ 10%).

Fig. 4. Estimates of investments in digital technologies



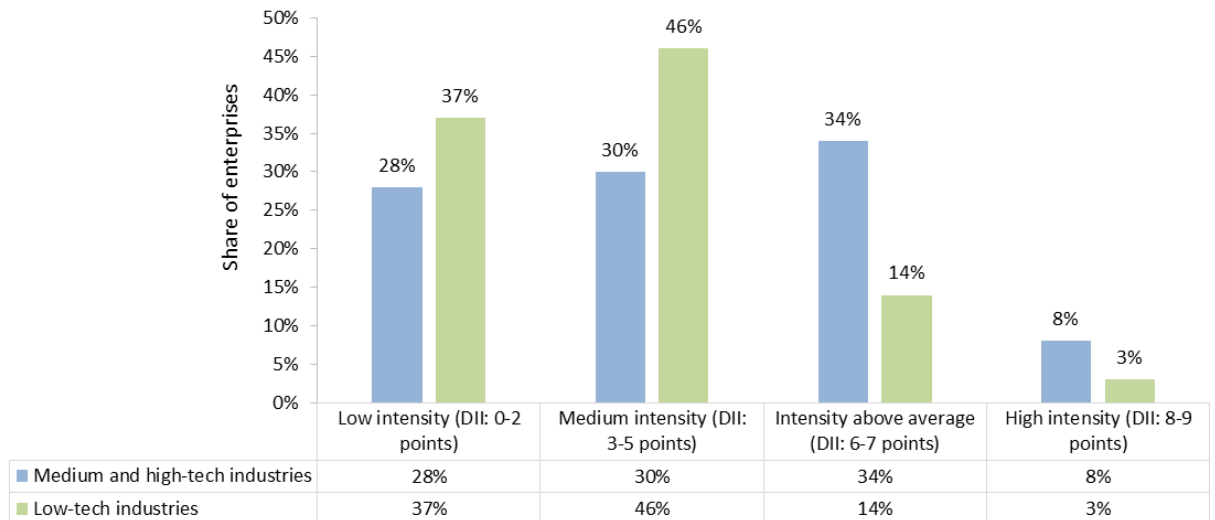
Source: authors' calculations

## 2. Digital Intensity Measurement (DII) Estimates

Fig. 5 shows the distribution of the calculated DII values for the results for 2020 among enterprises from the sample, divided into medium- and high-tech and low-tech segments. It can be noted that the segment of medium- and high-tech industries is most represented by enterprises with DII values above the average (6-7 points), while in the low-tech segment the share of enterprises with average DII (3-5 points) was the largest. In both segments, a significant share was occupied by enterprises with low DII (0-2 points), and the number of enterprises with high DII (8-9 points) was small, being slightly more represented in the medium and high-tech segment.



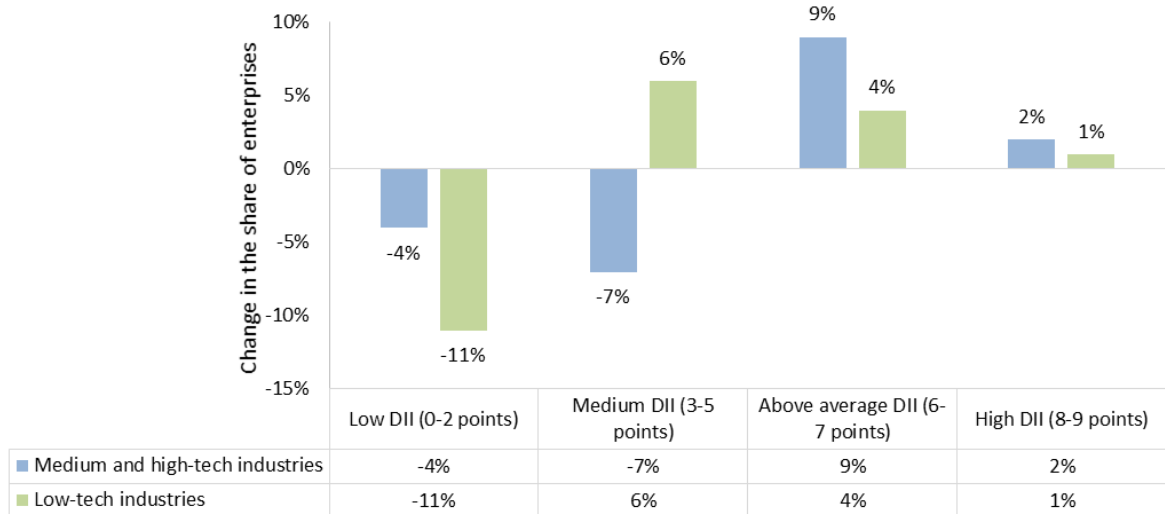
Fig. 5. Distribution of enterprises from two technology segments by DII value



Source: authors' calculations

Fig. 6 shows the changes in the share of industries from two technology segments in the groups of enterprises according to the value of DII (“low”, “medium”, “above average”, “high”) in 2020 compared to 2019. We can see considerable shifts towards higher digital intensity in 2020. In particular, this can be traced in a noticeable increase in the share of enterprises with the DII value “above average” both in the medium- and high-tech segment (to a greater extent, an increase of almost 10%) and in the low-tech segment (to a lesser extent, an increase of almost 5%). The situation in the low-tech segment was characterized by the flow of a significant share of enterprises from the group with “low” DII (decrease by more than 10%) to the group with “medium” DII (growth by more than 5%), which also undoubtedly became evidence of a leap in digital transformations in 2020. In the medium and high-tech segment, both in the group with “low” DII, and especially in the group with “medium” DII, there was a decrease, and the groups “above average” and “high” grew more actively than similar groups in the low-tech segment of the industry. Thus, DII calculations indicate that the medium and high-tech segment was ahead of the low-tech segment in terms of the level of digitalization in 2020, but in both segments there was a significant increase in digital intensity.

Fig. 6. Change in the share of industries from two technology segments according to the value of DII in 2020 compared to 2019



Source: authors' calculations

### 3. Assessments of the Impact of COVID-19 on the Digital and Investment Activity of the Manufacturing Industry

As a rule, crisis phenomena determine the procyclical nature of indicators of the business and digital climate, especially in terms of financial indicators, since in the context of a sudden collapse of the business environment, enterprises and organizations are faced with a drop in production activity, a reduction in profits and sources of funding, which leads to a suspension, or even a sharp slowdown in the rate of investment. However, one of the features of the current coronacrisis is its specific side, which has turned out to be a trigger of digital transformation for certain sectors of the economy. This section presents the results of the survey, reflecting the detailed assessments of business leaders regarding the impact of COVID-19 on the dynamics of digital activity and digital investment.

An analysis of the opinions of enterprise managers allows us to conclude that the aggressive impulses of the coronavirus crisis, which caused waves of uncertainty during 2020 and a general contraction of the dynamics of economic development, became, if not for most, then for many industries, the determining factors of one-stage and extremely negative changes in the state of the business climate. As shown by the results of a survey for the manufacturing segment as a whole, the pandemic caused a decrease in business activity in 40% of enterprises and contributed to its growth only in 8%. For 47% of industries, the impact of the crisis was neutral.

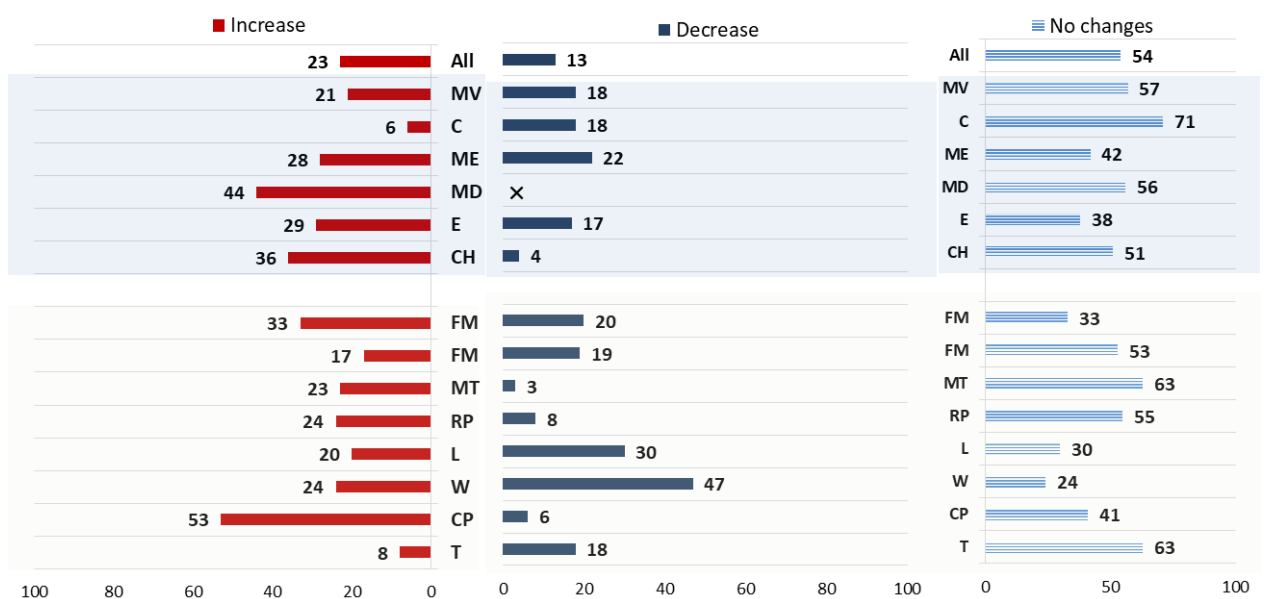
In contrast to the predominantly unfavorable changes in business climate estimates caused by the pandemic, digital activity in the manufacturing industry was not only more resilient to

shock, but also received some positive momentum (fig. 7). According to the results of the survey, the acceleration of the process of digital transformation due to the coronavirus crisis occurred in 23% of enterprises, while for only 13% this impact turned out to be negative. At the same time, for more than half of industries (54%), the negative impact did not affect the prevailing rates of digital activity. For example, companies producing computers, electronic and optical products became the leaders in terms of resistance to negative effects: more than 70% of executives stated that there was no change in digital activity associated with the pandemic.

The greatest acceleration of the “pulse of digitalization” occurred at the enterprises producing coke and petroleum products (53% of respondents noted an increase, 6% - a decrease); medicines and materials used for medical purposes (44% against 0%); chemicals and products (36% against 4%); furniture (33% against 20%).

*Fig. 7. Impact of COVID-19 on the dynamics of digital activity*

*(% of the total number of organizations)\**



*Source: authors' calculations*

*\* Note: the share of respondents who abstained from the answer is not shown*

Despite the pronounced background of positive changes in the dynamics of digital transformations, the pandemic did not act as a powerful catalyst for the growth of investment activity in technology, causing a relative acceleration in only a few sub-sectors of the processing segment and, rather, became some kind of benchmark for understanding the degree of the necessary reboot in the short and medium term (fig. 8). At the same time, it can be noted that the assessments of managers regarding the impact of the crisis on the dynamics of investment in digital products were divided with the prevailing dominance of opinions not only about its negative, but also neutral impact, amounting to 35 and 50% of all respondents, respectively. Only 5% of all

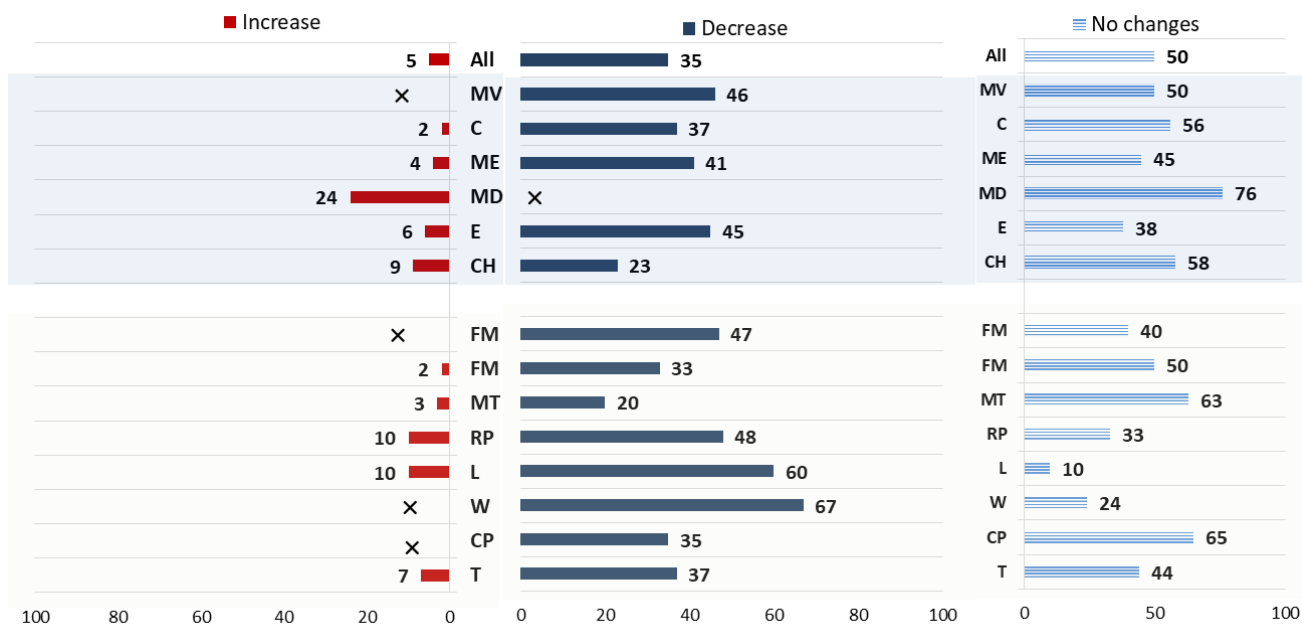
survey participants reported that the current crisis has led to an increase in investment activity and, first of all, among them were enterprises for the production of medicines and materials used for medical purposes - 24%.

Nevertheless, in individual industries, the response of the respondents indicated almost the decisive role of the coronavirus crisis, which caused a decrease in financial investments. Such sentiments were most accentuated by low-tech wearing apparel enterprises - 67% of respondents associated a decrease in investment in technology with the effects of a pandemic (the opposite effect was noted by 10% of respondents); leather and leather products - 60% (0%), rubber and plastic products - 48% (3%), furniture - 47% (0%).

Among medium- and high-tech industries, against the background of a slight predominance of neutral assessments, COVID-19 provided the most significant destabilizing effect on the investment activity of enterprises in the production of motor vehicles (a decrease was noted by 46% of respondents), electrical equipment (45%), machinery and equipment (41%). At the same time, among these industries, one should again single out enterprises for the production of computers, electronic and optical products, most of which (56%) retained the pre-crisis dynamics of investment, which has been characterized by noticeable growth in recent years.

*Fig. 8. Impact of COVID-19 on Technology Investment Dynamics*

(% of the total number of organizations)\*



Source: authors' calculations

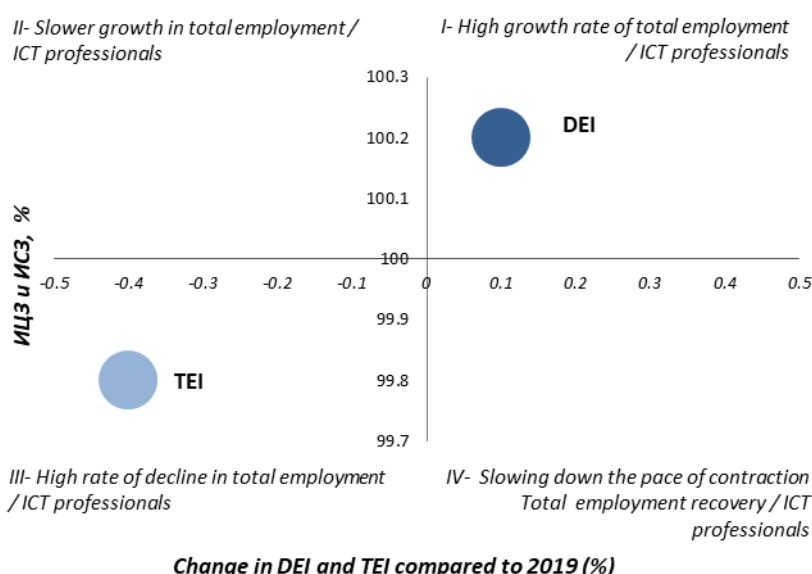
\*Note: the share of respondents who abstained from the answer is not shown

#### 4. Measuring the dynamics of the number of ICT specialists and total employment (DEI, TEI)

More detailed account about the newly formed trends in the digital climate in the context of a pandemic can be obtained from a survey that characterizes not only the dynamics of total employment in the segment, but also the number of specialists with digital competencies at enterprises, as one of the key factors in the digitalization process (fig. 9, fig. 10).

According to the trajectory of the Digital Employment Index (DEI), which aggregated the respondents' assessments regarding the changes in the number of employed ICT specialists, it can be concluded that in the processing segment during 2020 the intensity of the expansion of the share of the workforce with functional responsibilities in the ICT sector has slightly increased. Compared to 2019, the DEI for the segment as a whole increased by 0.1 percentage points up to 100.2%. The relevance of the preservation and development of digital transformations indirectly emphasizes the fact that against the background of the growth trend in the share of ICT specialists, the dynamics of total employment in the segment has shown a significant decline. The shrinkage of the workforce is indicated by the adjustment of the Total Employment Index (TEI), which decreased by 0.4 percentage points compared to 2019 up to 99.8%.

Fig. 9. Total and digital employment index



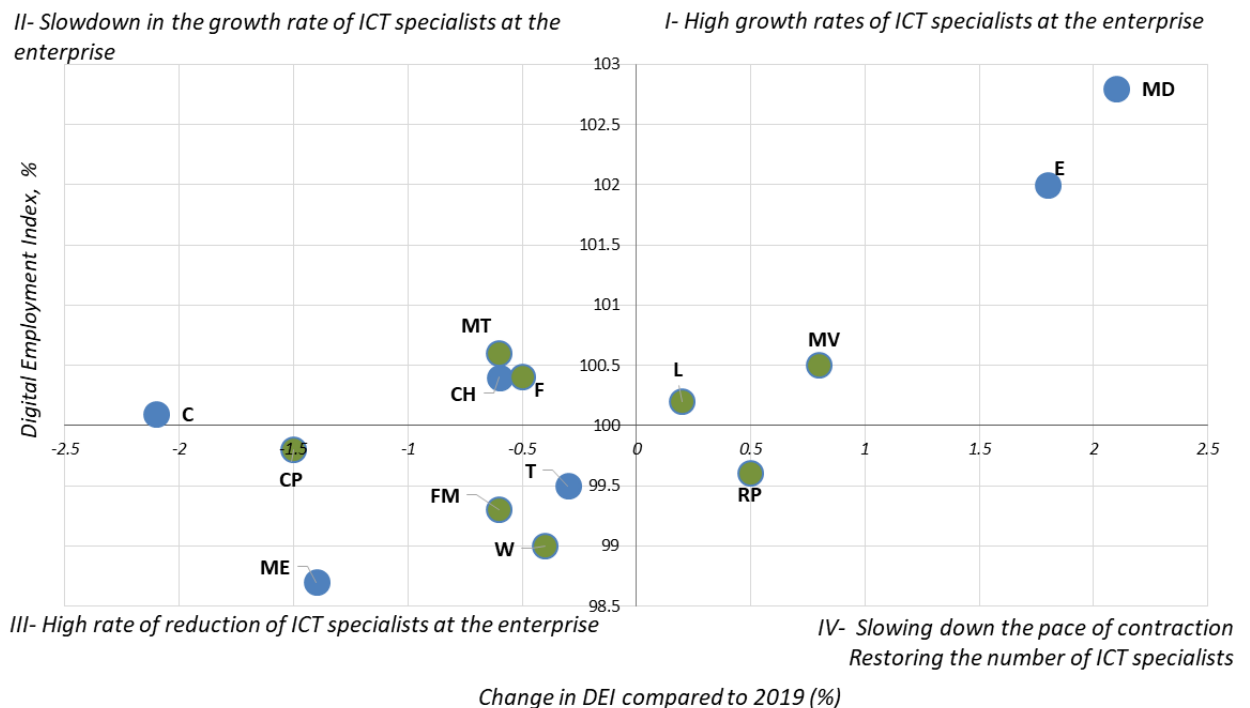
Source: authors' calculations

As shown by the sectoral spread of DEI values, the highest rate of expansion of the workforce by ICT professionals compared to 2019 occurred at enterprises producing medicines and materials used for medical purposes (the index grew to 102.8% by 2.1 percentage points) and electrical equipment (up to 102.0% by 1.8 percentage points). At the same time, at a more modest pace, the employment of personnel with ICT competencies continued at enterprises for the

production of motor vehicles, trailers and semi-trailers (DEI growth to 100.5% by 0.8%), as well as leather and leather products (up to 100.2% by 0.2%). The increase in demand for “digital personnel” occurred at enterprises producing rubber and plastic products, which was reflected in a noticeable reduction in the rate of their disposal: the index corrected to 99.6%, having risen by 0.5 percentage points. The contraction of human resources activity in the ICT field compared to 2019 accompanied the digital transformation of enterprises for the production of computers, electronic and optical products, chemical products, furniture and metallurgy.

Accentuated optimization of the personnel structure, including through the reduction of ICT specialists, was traced at enterprises producing machinery and equipment (reduction of DEI to 98.7 by 1.4%), finished metal products, except for machinery and equipment (up to 99.3% by 0.6%), wearing apparel (up to 99.0% by 0.4%), textiles (up to 99.5% by 0.3%), coke and petroleum products (up to 99.8% by 1.5%).

*Fig. 10. Sectoral Digital Employment Index*



*Source: authors' calculations*

The unprecedentedness of many components of the business and digital climate has exacerbated the problem of low levels of digital literacy in enterprises. According to the results of the survey, in 2020 the trend for the implementation of most complex digital solutions not by staff, but by the involved ICT specialists, has strengthened (fig. 11). Most of the ICT competency profiles are faced with a shortage of qualified personnel. At the same time, the accentuated trend emerging in 2019, consisting in the performance of an increasing number of high-tech tasks by our own employees, has received a slowdown.

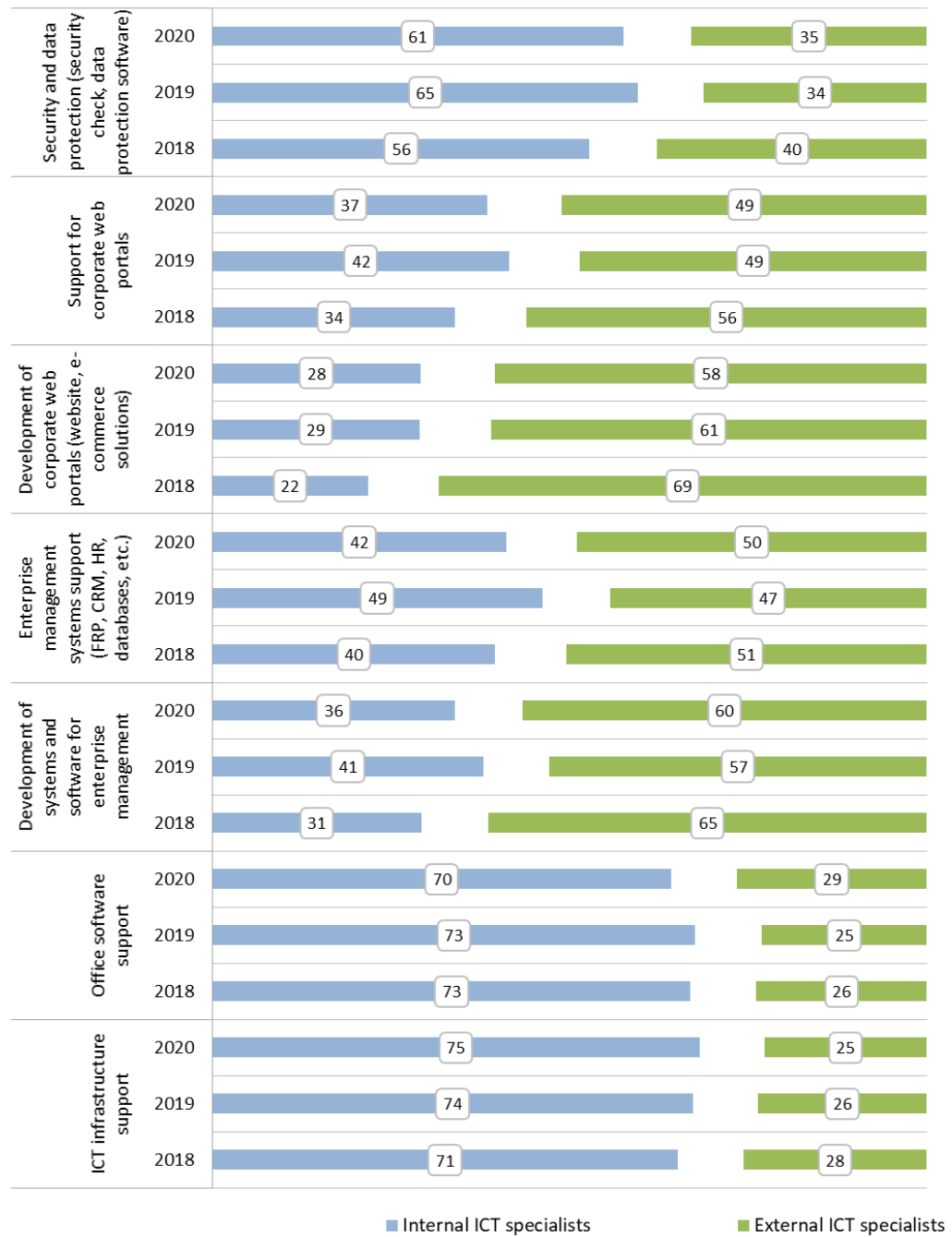
Compared to 2019, the greatest growth in the demand for external specialists was in the development of software systems for enterprise management: against the background of the growth of external specialists to 60 from 57%, the share of internal specialists decreased to 36 from 41%. A similar situation has developed with work to support enterprise management systems (work with ERP, CRM, HR and databases): up to 50 from 47% increase in external specialists and up to 42 from 49% reduction in the involvement of staff.

It is noteworthy that in 2020, higher professional skills were also required in simpler functions - to support office software (the share of external specialists increased to 29 from 25%), although the vast majority of their own specialists continued to perform these functions at enterprises (70%).

The interest in more professional ICT personnel was traced in the implementation of tasks aimed at developing security and data protection (35%), and also remained high enough for work related to the support of corporate web portals (49%).

The slowdown in the process of replacing internal specialists with external ones continued only in terms of the functions of supporting the ICT infrastructure of enterprises: compared to 2018, the number of employed internal specialists increased to 75 from 71%, and the number of external specialists decreased to 25 from 28%.

*Fig. 11. Distribution of external and internal specialists, performing functions in the field of ICT at enterprises  
(% of the total number of organizations)*



*Source: authors' calculations*

The growing need to attract external ICT specialists with higher professional skills against the background of a decrease in the involvement of internal staff (fig. 12), is consistent with the strengthening of negative feedback from respondents from almost all sub-sectors of the manufacturing industry for the limiting factor - “low level of digital literacy of specialists at the



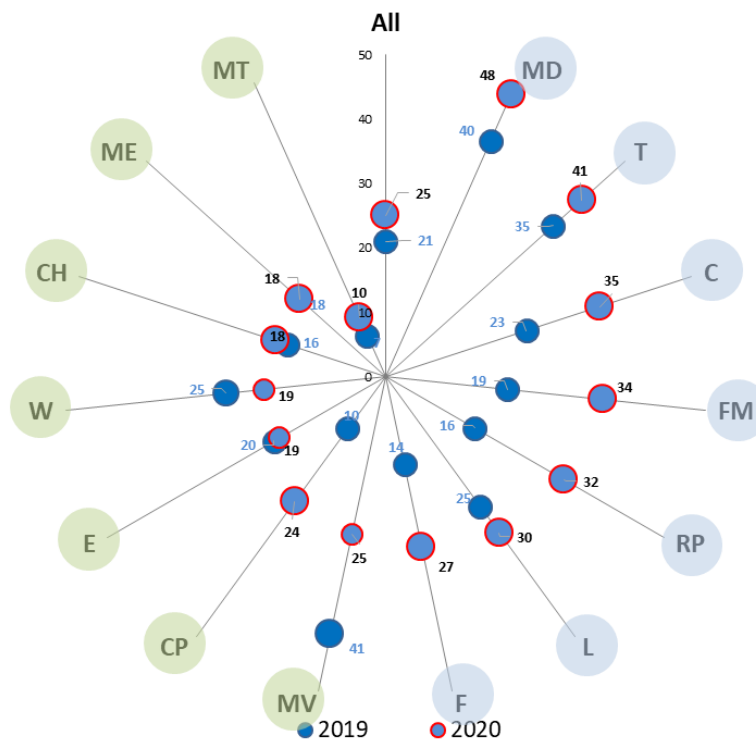
enterprise: insufficient experience in the field of ICT”, the aggravation of which in 2020 was noted at a quarter of enterprises (21% in 2019).

The leading positions in terms of the scale of the problem remained with medium- and high-tech enterprises, among which a particular deficit of digital competencies in the ICT field was found in the production of medicines and materials used for medical purposes, textiles, computers, electronic and optical products.

At the same time, the results of the survey showed that from the side of individual enterprises, the increase in negative assessments was twice or more. In particular, in 2020 this problem became especially acute in comparison with the pre-crisis year for the heads of enterprises producing rubber and plastic products (up to 32 from 16%), finished metal products, except for machinery and equipment (up to 34 from 19%), computers, electronic and optical products (up to 35 from 23%), coke and petroleum products (up to 24 from 10%), furniture (up to 27 from 14%).

A decrease in attention to the low level of digital competencies and insufficient experience in the implementation of technologies occurred at the enterprises for the production of motor vehicles and wearing apparel.

*Fig. 12. Limiting factor estimates “Low level of digital literacy of specialists at the enterprise: insufficient experience in the implementation of technologies and competencies in the field of ICT (% of the total number of organizations)*



Source: authors' calculations

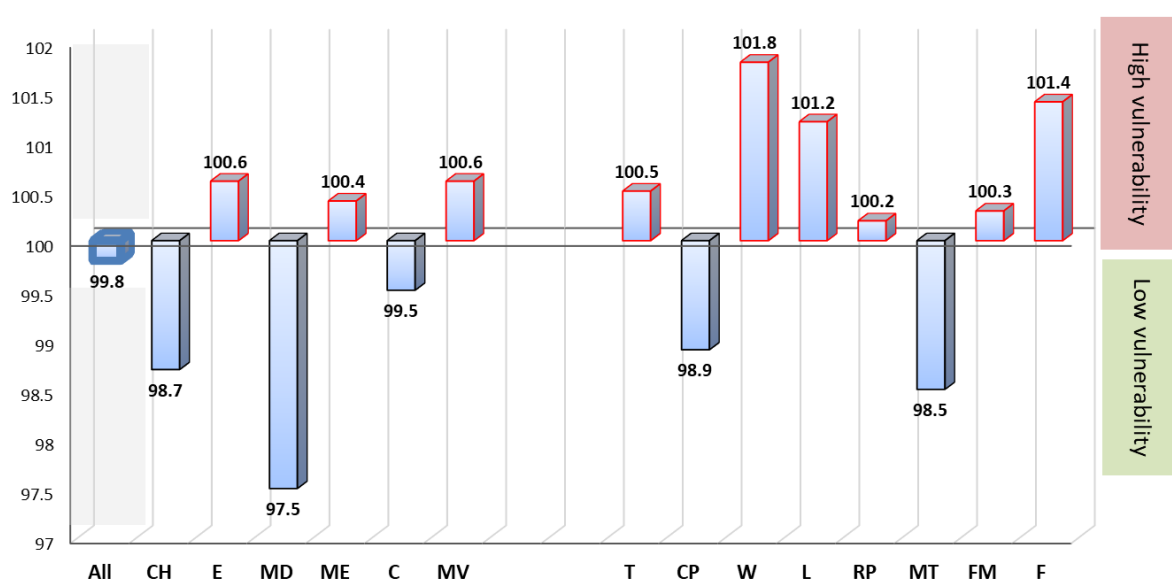
## 5. Measuring the vulnerability and adaptability of industries to digital transformation in a pandemic

The Digital Vulnerability Index (DVI), which demonstrates with its dynamics the aggregate reaction of managers to the “classic” market factors that limit the process of technological transformation, as well as individual estimates of the indicators of the observations program, measuring the effects of the coronacrisis shock, indicates that the processing segment has managed to withstand stress fluctuations in the market environment, which has been reflected in the final location being located in the zone of relatively low vulnerability (fig. 13). At the end of 2020, DVI amounted to 99.8%, but was at the most dangerous distance close to the turning point towards the negative dynamics.

Among the studied subsectors, enterprises producing medicines and materials used for medical purposes (DVI amounted to 97.5%), chemicals and chemical products (98.7%), coke and petroleum products (98.9%), machinery and equipment (98.5%) and computers, electronic and optical products (99.5%) showed a low vulnerability to classic problems, as well as to the negative messages of the pandemic.

The highest exposure to limiting restrictions and, accordingly, high digital vulnerability was demonstrated by enterprises from the group of low-tech industries. Among them, the most unfavorable value of DVI was recorded at enterprises for the production of wearing apparel (101.8%), furniture (101.4%), leather and leather products (101.2%).

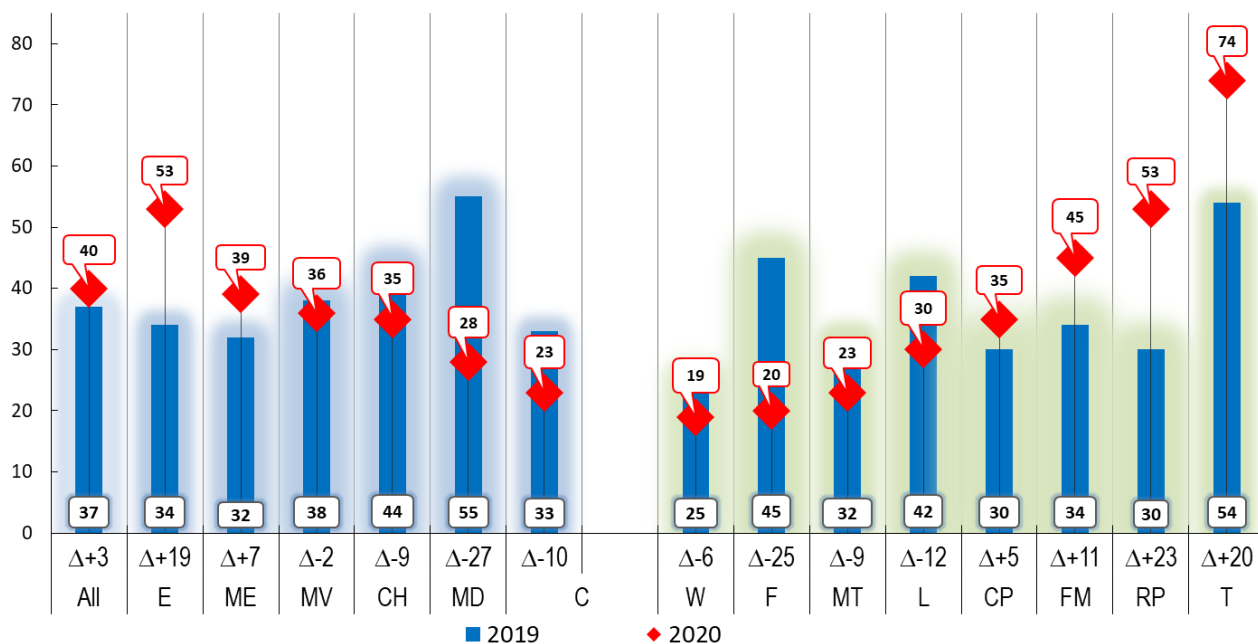
Fig. 13. Digital Vulnerability Index (%)



Source: authors' calculations

At the same time, the results of the survey allow us to state that the unfolding crisis did not have a serious negative impact on the respondents' assessments of the indicator characterizing the readiness of industries for digital transformation: their share, despite a slight increase, as in 2018-2019, was less than half of all survey participants (fig. 14). In 2020, the share of enterprises in the manufacturing segment increased to 40 from 37% in 2019, the leaders of which reported low adaptability to digital transformation.

Fig. 14. Enterprises with low adaptability to digital transformation



(% of the total number of organizations)

Source: authors' calculations

In the new economic reality, the most noticeable increase in such enterprises occurred in the group of low-tech subsectors, covering textile production (up to 74% from 54 in 2019), rubber and plastic products (up to 53 from 30%), finished metal products, except for machinery and equipment (up to 45 from 34%), coke and petroleum products (up to 35 from 30%). Among the high-tech subsectors, an increase in the unfavorable trend was recorded at enterprises for the production of electrical equipment (up to 53 from 34%), as well as machinery and equipment not included in other categories (up to 39 from 32%).

At the same time, during 2020, a number of industries left the unfavorable pattern, indirectly emphasizing the disproportionate impact of the coronavirus effects on the launched digital transformation processes. According to the survey, the most striking examples of such a change are the medicines industry, as well as the production of machinery and equipment, the shares of weakly adaptive enterprises in which decreased to 28 and 20%, although in 2019 they reached 55 and 45%, respectively.

A similar, but less pronounced background of changes was recorded for enterprises producing chemicals (down to 35 from 44%), computers, electronic and optical products (up to 23 from 33%), motor vehicles, trailers and semi-trailers (up to 36 from 38%). The low-tech segment also draws attention, the most noticeable increase in digital mobilization in which was noted at enterprises for the production of leather and leather products (the share decreased to 30 from 42%), furniture (down to 23 from 32%) and wearing apparel (down to 19 from 25%).

## **Conclusions**

In general, according to the results obtained, we can conclude that, despite all the negative consequences and uncertainty associated with the COVID-19 crisis, 2020 became, if not a turning point in terms of accelerating digital processes, but definitely a very significant point. Manufacturing businesses were both relatively resilient to the adverse business trends caused by the pandemic and were able to absorb the positive digital momentum generated by the pandemic.

From the point of view of the dynamics of the digital climate, the segment demonstrated more moderate changes, while the estimates of digital intensity indicate more active shifts in the intensification and spread of digital processes in 2020. The segment of medium- and high-tech industries turned out to have deeper digitalization than in the low-tech segment. However, when it comes to digital investment, the pandemic has proven to be a rather weak catalyst, playing an important role in only a few sub-sectors, such as pharmaceuticals, which overall experienced the most powerful digital boom in 2020, standing out from the rest of industrial activities.

Also, the COVID-19 crisis highlighted the problem of a low level of digital literacy in enterprises, which, in the face of a sharp increase in the need for digital solutions, broke the previously established trend of increasing the proportion of full-time employees performing ICT tasks. Now companies had to actively seek out external ICT specialists.

Further directions for the development of research problems posed in this work may consist in measuring digital sentiment and progress in the new post-pandemic reality of other sectors of the economy, as well as purely technological transformations through point and aggregated instruments and meters. For example, trade organizations, the financial sector, enterprises for the production of computers, electronic and optical products, and the pharmaceutical segment from the manufacturing sector are of great interest for future research. At the same time, it is advisable to focus on certain advanced technologies, say, “green” technologies or Industry 4.0 technologies, which imply the study of digitalization through an alternative prism, which allows for a more

detailed analysis that is closer to the features of industrial production than a standardized measurement of the level of digital intensity of enterprises or the state of the digital climate.

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