

DIGITAL MATURITY OF MANUFACTURING ENTERPRISES

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Abstract

The digitization of the world economy is a natural evolutionary change due to the dynamic development of information and communication technologies. The introduction of digital technologies and the use of the benefits of digital transformation comes from a general desire to systematically increase the efficiency of key industries of national economies. The paper analyses the level of technological development of selected manufacturing enterprises and suggests the ways of using internal digital instruments and measures to achieve their "digital maturity". The analysis contains manufacturing enterprises of various levels of digitization from high-digitized through medium-digitized to low-digitized. It is based on official statistics and public financial statements and the index method is used to assess levels of digitization of individual manufacturing enterprises. The results show the causes and consequences of different levels of digitization of individual manufacturing enterprises and serve as a fundamental for further theoretical and applied research on the trajectories of the development of the "digitization" of manufacturing enterprises.

Key words: digitization, manufacturing industry, internal instruments

JEL Code: M31, O18, O33

Introduction

The digital transformation of economic processes is a priority for the development of national economies around the world. It brings new business models and manufacturing processes using digital technologies (Yang & Gu, 2021). According to the digital economy indicators developed by the National Research University Higher School of Economics (HSE University, 2021), Sweden is a world leader in the internet communication (Inclusive Internet Index: 87.4), the United States is a world leader in digital competitiveness and network interaction (Global Connectivity Index: 87), Denmark is a world leader in e-government (E-Government Development Index: 0.98), and Switzerland along with the Netherlands are world leaders in e-commerce (B2C E-Commerce Index: 95.9 and 95.8).

Scientific studies dealing with the global digital economy show that digitization is evolving with varying intensity in all economic industries (Popkova, Bogoviz, & Sergi, 2021), mainly based on the evidence that the digitization of industrial processes has a positive effect on the economic growth (Felsberger, Qaiser, Choudhary, & Reiner, 2022). Digitization is a modern trend focused on a strategic (long-term) perspective (Shirinkina, 2018) and the digital economy represents a new environment supporting the development of vital activities of industrial businesses (Gonzalez & Gulbrandsen, 2021). This environment is very dynamic and challenging, characterized by the rapid development and implementation of digital innovations (Demir, Gunduz, Kayikci, & Paksoy, 2022). This raises questions about the digital maturity of different manufacturing enterprises and their readiness to meet challenges of the global digitization.

1 Goal and method

The paper analyses the level of technological development of selected manufacturing enterprises and suggests the ways of using internal digital instruments and measures to achieve their "digital maturity". The analysis is based on official Eurostat statistics and public financial statements revealing the use of information and communication technologies (ICT) in selected manufacturing enterprises. The analysis contains a sample of 474 manufacturing enterprises of various levels of digitization from high-digitized through medium-digitized to low-digitized (the marginal sampling error does not exceed $\pm 5\%$ at a confidence level of 97%). To determine the key trends in the development of digital maturity of selected manufacturing enterprises, data from 2018 to 2020 were analyzed. By an analysis of available materials, specific relative indicators characterizing the level of digital maturity of manufacturing enterprises in the manufacturing industry were defined by the authors (see Fig. 1).

A methodology based on the index method was used to assess the levels of digital maturity of individual manufacturing enterprises. At the first stage of the analysis, the standardized coefficient is calculated according to the formula (1):

$$k_i = \frac{x_i}{\max(x_i)} \quad (1)$$

where x_i is the value of the i^{th} target indicator for a separate object of study;
 $\max(x_i)$ is the maximum value of the given indicator from all studied objects.

Fig. 1: Indicators characterizing the level of digital maturity of manufacturing enterprises

The share of enterprises using ICT in the total number of enterprises (%)
The share of enterprises having web pages in the total number of enterprises (%)
The share of enterprises that have provided their employees with mobile internet in the total number of enterprises (%)
The share of enterprises using third-party open source operating systems in the total number of enterprises (%)
The share of enterprises using global information networks, except for the internet in the total number of enterprises (%)
The share of enterprises using cloude services in the total number of enterprises (%)
The share of enterprises using electronic data interchange in the total number of enterprises (%)

Source: authors

At the second stage of the analysis, the index of the level of digital maturity of each object of study is determined according to the formula (2):

$$I_j = \sqrt{\frac{\sum_{i=1}^n k_i^2}{n}} \quad (2)$$

where k is the standardized coefficient;

n is the number of indicators.

This procedure is used to assess levels of digital maturity of individual manufacturing enterprises to identify key areas for the development of digital maturity of manufacturing enterprises through their digital tools.

2 Results

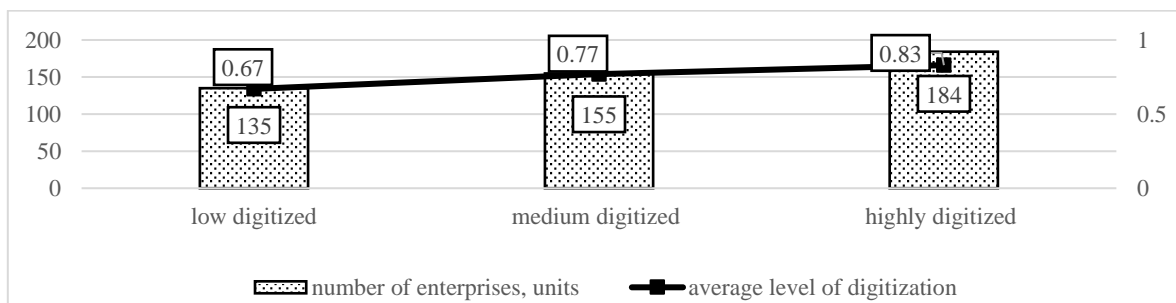
The results of the authors' analysis of the digital maturity of individual manufacturing enterprises are presented from three perspectives: 1) the level of digitization of individual manufacturing companies; 2) labor resources and costs of information and communication technologies; 3) internal digital instruments and measures for digital maturity of manufacturing enterprises.

2.1 The level of digitization of individual manufacturing enterprises

The introduction of digitization concerns both the technological development of the concept of the factory of the future, including digital, smart, and virtual factories, service business models, or predictive maintenance (Bibby & Dehe, 2018), and broader organizational aspects such as strategy, human resources, or finance (Hanelt et al., 2020). Digitization represents a continuous

transformation phase for manufacturing enterprises that want to fully integrate their business functions and manufacturing systems with data from the entire product lifecycle (Castelo-Branco et al., 2019). The analysis of the level of digitization of individual manufacturing enterprises contains a sample of 474 manufacturing enterprises of various levels of digitization (see Fig. 2) from high-digitized (38,7%) through medium-digitized (32,8%) to low-digitized (28,5%). Low-digitized manufacturing enterprises include enterprises with a low level of technological complexity – the production of clothing, tobacco products, food products, printing activities, or wood processing. Medium-digitized and high-digitized manufacturing enterprises are characterized by complex technologies and high requirements for staff qualifications – production, installation, and service of metal, rubber, and plastic products, machine tools, motor vehicles, electrical equipment, computers, electronics, chemicals, drugs, or materials for medical purposes.

Fig. 2: Distribution of manufacturing enterprises by the level of digitization

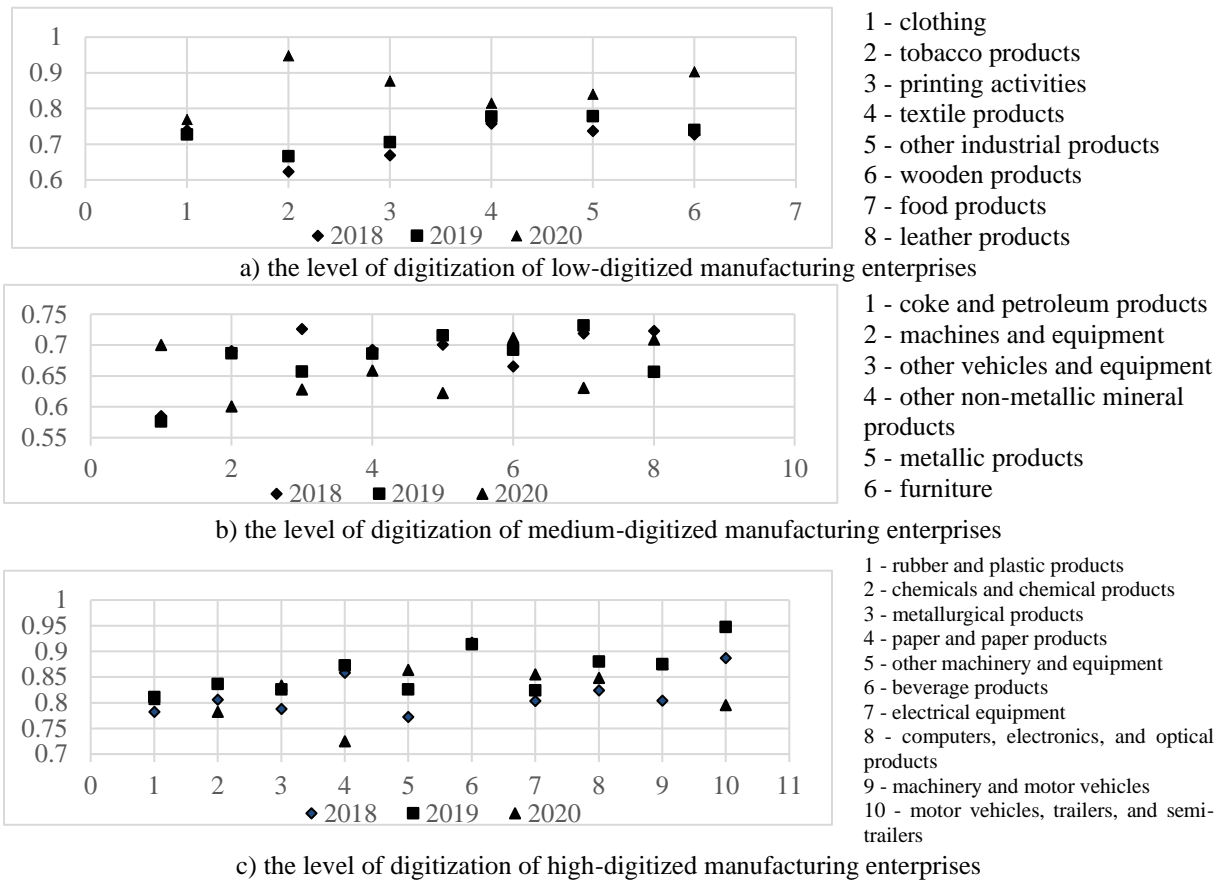


Source: authors

According to the analysis, the level of digitization in manufacturing enterprises did not decrease significantly due to the COVID-19 pandemic in 2020 compared to 2019, however, due to anti-coronavirus measures, digitization in some enterprises was not a priority (see Fig. 3). In the comparison of manufacturing enterprises, a heterogeneous change in the value of the level of digitization can be observed, expressing both the specific activities of manufacturing enterprises and the importance of digital solutions for productivity, competitiveness, and development. Among low-digitized manufacturing enterprises (see Fig. 3a), the level of digitization decreased the most in enterprises producing clothing (by 0.12 points), tobacco products (by 0.90 points), and providing printing activities (by 0.10 points). Medium-digitized manufacturing enterprises (see Fig. 3b) have improved their level of digitization, especially in enterprises producing machinery (by 0.32 points) and other vehicles (by 0.21 points). Among high-digitized manufacturing enterprises (see Fig. 3c), the level of digitization increased in enterprises producing vehicles, trailers, and semi-trailers (by 0.07 points) and metallurgical materials and electrical equipment (by

0.05 points). The most significant negative change in this group was in enterprises producing beverages (the level of digitization decreased by 0.26 points), paper (by 0.3 points), and drugs and materials for medical purposes (by 0.09 points). The growth of digital activities has been reflected in the development of technologies orientated on the use of internet services, cloud services, or e-commerce.

Fig. 3: Dynamics of changes in the level of digitization of manufacturing enterprises

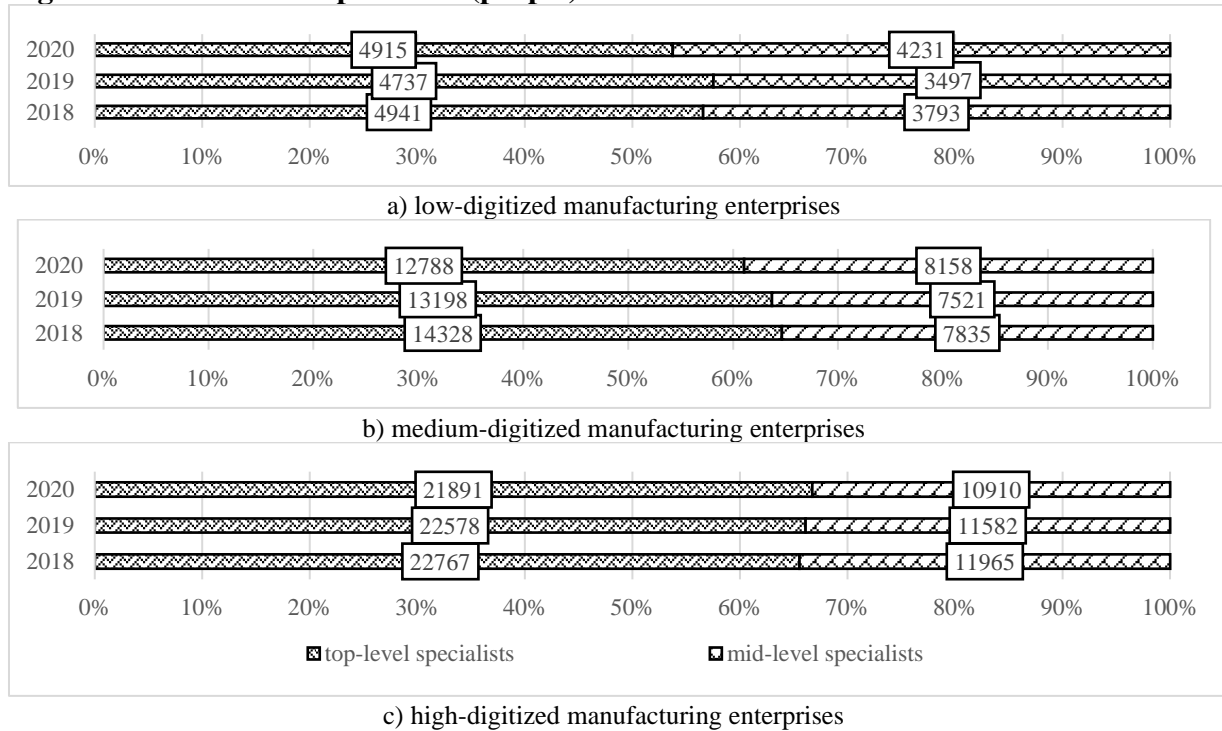


Source: authors

2.2 Labor resources and costs of information and communication technologies

The use of information and communication technologies (ICT) requires qualified people and the continuous development of their skills. The intensity of technological changes has created a significant gap between actual and required skills (Fernández-Portillo, Almodóvar-González, Sánchez-Escobedo, & Coca-Pérez, 2022). The analysis of the number of ICT specialists in manufacturing enterprises as one of the key factors of digitization showed that in low-digitized manufacturing enterprises, the number of ICT specialists increased in 2020 compared to 2018 (by 5.0%, see Fig. 4a). The highest increase in the number of ICT specialists since 2018 occurred in enterprises producing tobacco products (by 23%) and food products (by 11%).

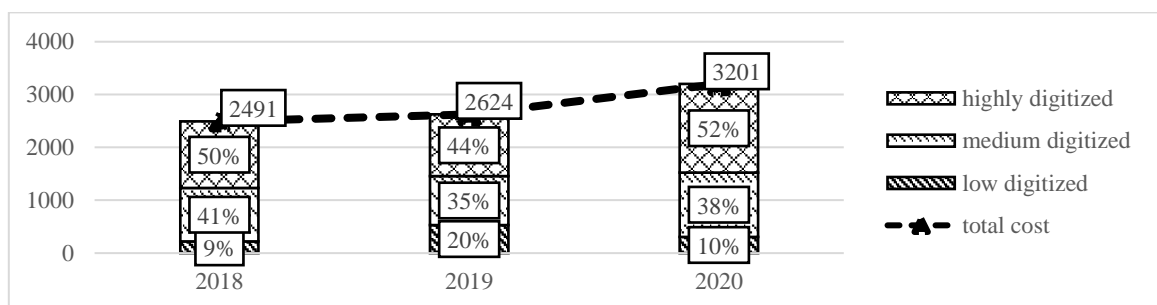
Fig. 4: Number of ICT specialists (people)



Source: authors

In medium-digitized manufacturing enterprises, the number of ICT specialists decreased in 2020 compared to 2018 (by 5.0%, see Fig. 4b), similarly to high-digitized manufacturing enterprises (by 6.0%, see Fig. 4c). The decrease in the number of ICT specialists compared to 2018 occurred in enterprises producing machine tools and chemicals (by 22.0%) or in enterprises producing machinery, vehicles, trailers, and semi-trailers (by 20.0%). The increase in the number of ICT specialists in 2020 occurred in enterprises producing drugs and materials for medical purposes (by 13.0%), furniture (by 18.0%), or rubber and plastic products (by 22.0%). Digitization improves the economic results of manufacturing enterprises. However, the development of digitization is accompanied by increasing costs for the introduction and use of digital technologies (see Fig. 5).

Fig. 5: Expenses on information and communication technologies (millions of dollars)



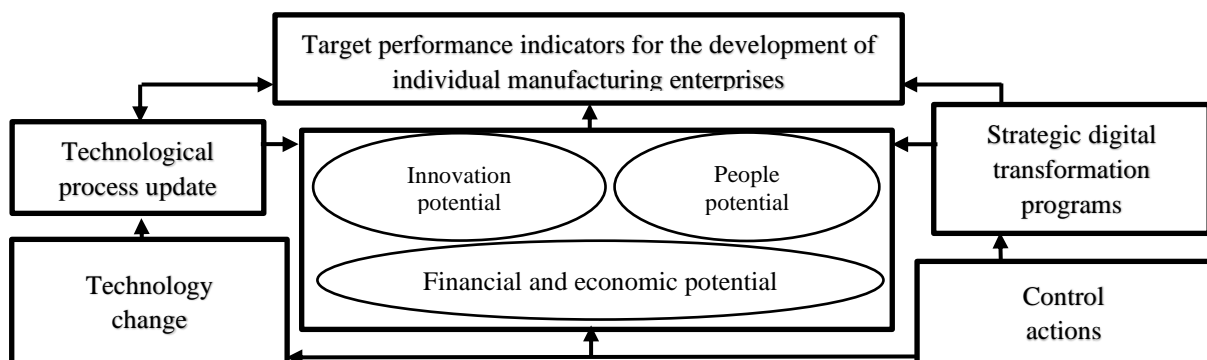
Source: authors

The analysis showed a 1.5-fold increase in investments in the technological development of individual manufacturing enterprises during 2020 compared to 2018. The amount invested was 3,201 million dollars. Investments in digitization have almost doubled production in individual manufacturing enterprises – production of drugs and materials for medical purposes (+98.0%), production of paper (+108.0%), production of furniture (+128.0%), wood processing (+162.0%), production of rubber and plastic products (+182.0%), production of computers, electronic, and optical products (+215.0%). The largest part of the costs for the implementation and use of digital technologies falls on the purchase of equipment (36.9%) and the payment for telecommunications services (47.0%). Since the launch of national digital transformation programs and their alignment with global digitization trends, manufacturing enterprises have been steadily increasing their digital competencies, accompanied by the use of supporting tools, building specialized digital platforms, and optimizing their infrastructure.

2.3 Internal digital instruments and measures for digital maturity of manufacturing enterprises

To achieve the improvement of manufacturing processes through digitization, it is important to measure the impact of the introduction and use of digital technologies. To do this, manufacturing enterprises must first determine the appropriate performance indicators and then compare the results achieved with the required change in productivity. Fig. 6 shows a model of internal digital instruments for the development of digitization of manufacturing enterprises based on the use of business analytics to improve manufacturing processes and achieve the digital maturity of manufacturing enterprises.

Fig. 6: Model of internal digital instruments and measures for the development of digitization of manufacturing enterprises



Source: authors

The value of the internal digital instruments and measures is determined by the ability of manufacturing enterprises to use available data to identify opportunities and threats, activate innovative, human, and financial resources, or reorganize technological processes as needed. The purpose of internal digital instruments and measures is to help manage the target performance indicators for the development of a manufacturing enterprise. The ability to collect and process data on the operation of the enterprise and the use of this data to manage the enterprise to achieve target performance indicators is one of the key aspects of technological change and achieving digital maturity. The development of the innovative, human and financial potential of manufacturing enterprises should be supported by strategic digital transformation programs at the state level (Gorokhova, Goncharov, Stepanova, Zvereva, & Valigursky, 2020). A digital solution can have a direct or indirect impact, considering cause and effect relationships (Matt, Hess, & Benlian, 2015). The reconfiguration of the technological processes of individual manufacturing enterprises will of course be the result of both the development of technical competencies and the creation of flexible and highly efficient production based on digital platforms (Sekerin, Dudin, Gayduk, Bank, & Gorokhova, 2019).

Conclusion

Both the analysis and the findings of other secondary sources demonstrate the importance of the digital maturity of individual manufacturing enterprises for the development of the enterprises themselves and entire economies in the world of digital technologies. The development of digitization in individual manufacturing enterprises must be based on the systematic assessment of digital maturity as well as the benefits and costs of the implementation and use of digital technologies through a system of internal digital instruments and measures. The analysis showed different levels of digital maturity of surveyed manufacturing enterprises and their strengths and weaknesses in terms of technical competencies and information and communications technologies needed and used. Based on the analysis of the concepts of digital maturity of manufacturing enterprises, three potential areas for achieving the target indicators of the development of digitization of manufacturing enterprises were identified, namely innovation, people, and finance and economy, which subsequently change under the influence of a group of control actions to achieve desired digital maturity. The proposed model of internal digital instruments and measures for the development of digitization of manufacturing enterprises focuses on the priority areas of demanded digital technologies in industrial production in the future - neurotechnology and artificial intelligence, wireless communication technologies, and virtual and augmented reality.

The main benefit of the analysis is a different view of the theoretical and practical fundamentals of digital maturity and its impact on the development of digitization of manufacturing enterprises. Within the digitization of individual manufacturing enterprises, it is necessary to monitor the impacts of digital technologies on the achievement of target performance indicators. This could be supported by the proposed model of internal digital instruments and measures, which focuses on technological advancement and creating conditions for the development of individual manufacturing enterprises through the digitization of their processes.

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