The CAP and national priorities within the EU budget after 2020

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16. Smart Manufacturing – potential of new digital technologies and big data in the food industry

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Abstract

New digital technologies are currently becoming one of the main sources of building a competitive advantage for enterprises. The Internet of Things and big data are opening the previously unknown possibilities for optimising production processes and improving the productivity. The speed, nature and scope of technological changes let us talk about the fourth industrial revolution. The chapter discusses chances related to the use of new digital technologies in the process of implementing the smart manufacturing concept in food industry enterprises. Attention is focused on the benefits of applying analyses of big data. What will be presented are the major types of data used in analyses of big data, characteristics of smart processing and areas for the possible application of digital solutions (inter alia, digital twins) in the food industry.

Keywords: digitisation, competitiveness, food industry, big data, digital twin

JEL codes: L16, L20, L66, O14, O31, O33

16.1. Introduction

Building a smart food economy – smart farming, smart food manufacturing and smart and agile food supply chains is one of the key challenges currently facing the Member States of the European Union (EU). The smart food economy assumes the intense use of information and communication technologies and innovative digital solutions (e.g. the Internet of Things, cloud computing and big data) for complex planning and management of food production and distribution processes. In line with the European Commission's proposals, in the next EU financial perspective for 2021-2027 actions for smart farming are to be covered with dedicated support from the Common Agricultural Policy budget [European Commission, 2017]. Building a smart food economy is also to be supported by structural policy measures, the new Digital Europe programme and the EU Framework Programme for Research and Innovation – Horizon Europe [European Commission, 2018].

It is expected that the widespread use of digital technologies and tools will lead to the more competitive, more efficient and more environment-friendly agri-food sector. According to many analysts, the digitisation of the food economy can be a milestone in tackling global problems and challenges related to the growing demand for food in the world. The technologies of precise use of the means of production, supported by advanced data analytics, also give hope to reduce the negative impact of agriculture on the speed of climate change [Walter et al., 2017]. However, the agri-food sector is at the very beginning of its path to digital transformation. In the case of agriculture, the basic problems are deficiencies and limitations in the area of telecommunications infrastructure in rural areas, unequal access to new technologies and advanced agricultural equipment and an insufficient level of digital competence of farmers. In the other links of the agri-food chain, digitisation processes are more advanced, yet still insufficient to talk about the digital breakthrough in the sector. In addition to financial constraints, the barriers are the lack of the vision and strategy of digitisation adjusted to the capacity and needs of individual entities and the limited knowledge of new digital technologies.

The digital transformation-related improvement in the planning, implementation and control of production and sales processes is particularly important for food industry enterprises. In fact, the smart industrial production enables building sustainable competitive advantages in the more and more demanding international markets. The objective of this chapter is to review the opportunities offered by the smart manufacturing concept and new digital technologies to food industry enterprises. The first part will explain the concepts of smart manufacturing, big data, digital twins. The second part of the chapter presents exemplary applications of the smart manufacturing concept in food industry enterprises, with a particular focus on the context of the operation of such enterprises in Poland. The chapter ends with the summary and conclusions.

16.2. Smart manufacturing

The smart manufacturing concept is defined as the intense use of data, digital technologies and robots at the level of the production hall and outside of it, resulting in smart, efficient and responsive actions [Wallace and Riddick, 2013; Thoben, Wiesner and Wuest, 2017]. It is indicated that smart manufacturing is a natural consequence of the emergence and dissemination of cyberphysical systems in the economy and business. These systems, combining the digital world with the real world, allow to gain fuller and faster insight into production processes and operating conditions of enterprises. The consequence of their emergence are also changes in the manufacturing paradigms, called by some the fourth industrial revolution (Industry 4.0). The paradigm of the mass and automated production, being a basis of the previous industrial revolution, is progressively displaced by the paradigm of the personalised production adjusted to individual and dynamically changing expectations and needs of consumers. The qualitative improvement with regard to the conceptualisation, planning and management of the production process is enabled by advanced analytics, modelling and simulations based on real-time data and historical data, recorded and transmitted over the network of machines, devices and sensors interconnected under the Internet of Things [Davis et al., 2012]. Ultimately, the enterprise operating in accordance with the smart manufacturing concept should integrate data and information from various sources, including data on the customers, partners and social environment. In this way, it has the potential to become a fully smart organisation which uses its available resources, energy and material inputs in an optimal way allowing to minimise costs, improve the environment and strengthen the competitiveness [Davis et al., 2012].

16.3. Big data analyses – basis for the development of smart enterprises

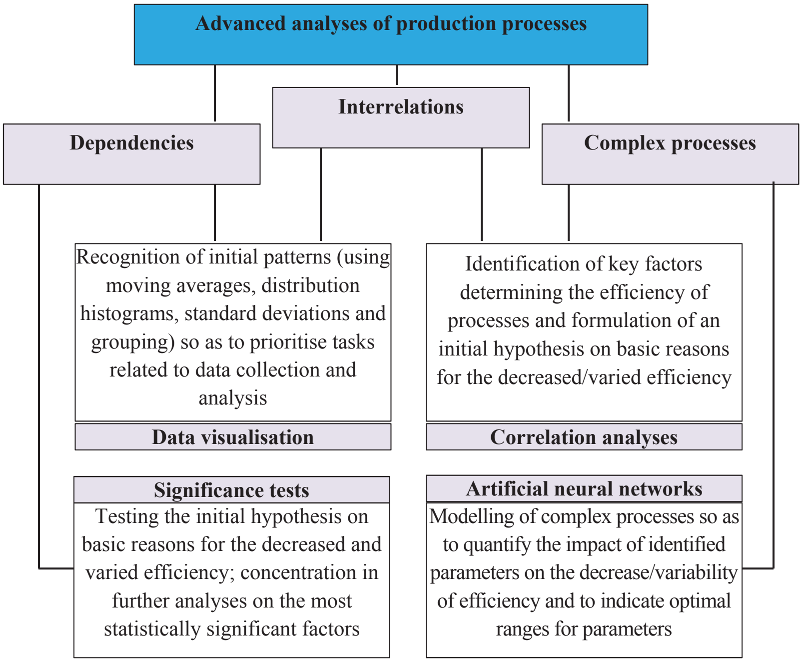
A central element building smart enterprises and industry 4.0 is the data and its real-time analysis, allowing to make more accurate and effective decisions. Thanks to new technologies and digitisation of many areas of socio-economic life, larger is not only the size and amount of data to be analysed but also its variety and speed with which it appears. What appears in addition to traditional structured data (inter alia, from IT systems for planning corporate resources), is unstructured data (images, videos, signals, text files), partially structured and hybrid data, data from multimedia, residual data (traces and by-products of Internet and mobile user activity), geolocation data, social media data, open data, data generated by machines and other types of data [Mayer-Schönberger and Cukier, 2013].

The growing content of digital data, including real-time data streams, is referred to as big data. Data related to the operation of the enterprise is usually collected at long intervals which results in entries in a form of time series [Munir et al., 2018]. Big data itself does not constitute values for the enterprise until it is properly analysed. Obtaining results useful for the enterprise requires the use of appropriate databases, data purification, preparation of data for analysis, application of appropriate analysis and modelling methods, and visualisation. A significant part of big data analyses uses advanced methods and solutions, including machine learning and artificial intelligence algorithms [Tao et al., 2018]. Traditional analyses use conventional algorithms and data that has been previously stored in information systems databases. In the era of big data – thanks to automation, artificial intelligence and cloud computing – analyses can be performed in real time. New results are available as soon as there is new data in the databases or other changes are made to these databases.

As noticed by Michael Porter and James Helbilman [2015], the revolution related to constantly growing digital data resources, which is of key importance to smart manufacturing, leads to new conditions of competition among enterprises. Big data can be used for descriptive, diagnostic, predictive and prescriptive analyses. In other words, these analyses can be used for objectives related to describing and explaining phenomena and processes relevant to the enterprise and for objectives related to predicting events or problems within the enterprise and in its environment and prescribing anticipatory and preventive actions. The automation of some analytical processes and new sources and types of data to be analysed, including in particular the data flowing to the Industrial Internet of Things in connection with the sensor systems for machines, production lines and products, open up new opportunities and perspectives for enterprises. The major benefits of big data analyses for production enterprises include: a) more comprehensive insight into production processes; b) discovering new dependencies and facts; c) increasing the production efficiency; d) improving the production quality; e) greater precision in forecasting the supply and demand for individual products; f) traceability of products; g) anticipating failures and breakdown of machinery; h) ensuring the maintenance of equipment operation; i) estimating the impact of the daily production on financial results; j) improving product lifecycle management [Mikalef et al., 2017; Munir et al., 2018]. The basic scheme for advanced analyses of production processes in the enterprise is presented in Figure 1.

The implementation of advanced big data analytics can be a big challenge for many enterprises. Among the main obstacles, there are the lack of capital for development, limited cooperation among individual departments in the enterprise, diversified types and formats of data in analyses, and the lack of adequate staff resources [Nikolic et al., 2017; Munir et al., 2018]. Even greater challenges are associated with analyses of processes outside the production plant [cf. Meriton and Graham, 2016]. As part of the smart manufacturing concept, this type of analyses plays, however, an equally important role. It can bring about a significant improvement in the functioning of supply chains, by contributing to the strengthening of the enterprise's competitive position. It may also indicate new development directions for the enterprise and new outlet markets.

Figure 1. Use of advanced data analytics for improving production processes in the enterprise



Source: study based on Munir et al., 2018., p. 152.

16.4. Digital twin paradigm

The distinctive feature of a smart enterprise of the Big Data era is its digital twin. In brief, a digital twin stands for a digital reflection of systems, processes and effects of the enterprise's production activities in the virtual world. The concept of digital twins was born in the United States at the beginning of the 2000s as a response to a need to introduce improvements into the product lifecycle management process [Uhlmann, Hohwieler and Geisert, 2017]. One of more frequently quoted definitions of a digital twin indicates that it is a set of virtual information constructs fully describing a potential or finished product, starting with the smallest components at the micro level, and ending with the complete whole at the macrogeometric level [Grieves and Vickers, 2017]. Assuming that the description is complete, the information that is obtained by means of physical and direct testing of the product can also be obtained by using its digital reflection.

The concept of digital twins can be considered a new paradigm for the functioning of enterprises in the digital age. Currently, using dedicated software it is possible to create evolving, digital representation of both products and processes and services [Beetz, 2017; Qi et al., 2018]. Thanks to sensors and data transmission systems, we can see a virtual reflection of what happened to objects in the past and what happens to them now. It is also possible to carry out forecasts and simulations of how objects concerned will be functioning in the future. These solutions lead to a number of benefits – from reducing the costs associated with maintenance of machinery and production lines, to reducing the number of failures, defects and other problems in final products. After all, the creation of complete digital models and reflections of products, processes and services – due to the complexity of the multidisciplinary modelling tasks – is still a difficult and challenging task. For this reason, more popular are partial models created for specific purposes, inter alia, simulation analyses of machinery's kinematic behaviour or prediction of machinery wear [Uhlmann, Hohwieler and Geisert, 2017].

It can be expected that the more and more common use of sensor technologies and the Internet of Things will be conducive to the development of the software market for the benefit of digital twins. Some high-tech companies are already offering solutions that are to lead to the full digital transformation of enterprises (inter alia, Siemens and its software for enterprises of various sectors and industries, including the brewing industry) [Siemens, 2017].

16.5. Smart manufacturing in the food industry in Poland

The food industry is classified as a low-tech sector. At the same time, it is characterised by a relatively low level of innovation, although it should be stressed that Polish food industry companies, especially beverage producers, are positively distinguished from other low-tech industries in terms of innovative activity they undertake [Firlej and Żmija, 2014; Grzybowska and Juchniewicz, 2014]. In the last two decades, the main source of the competitive advantages of Polish food producers were low prices and low production costs [Szczepaniak, Ambroziak and Kosior, 2018]. The effectiveness of price-cost strategies, both in the domestic and in foreign markets, limited the interest of companies in investing in innovative activities. An important part of technological innovations, related mainly to the modernisation of production facilities and machinery parks, has been implemented during the period of preparing for the EU membership and in the first years after joining the organisation. Currently, thanks to modern machinery and automated production lines, the technological level of food processing in Poland does not differ from the processing level in plants operating in the most advanced European economies [Kowalski, 2017].

Today, the food industry is among the most competitive branches of the Polish economy. Companies in this sector generate about 3% of GDP and employ about 450 thousand people. At the same time, the food and beverage production accounts for about 13% of the global production value in the national economy

[Statistical Yearbook of Industry, 2017]. One of the most significant indicators of the good competitive position of Polish food industry are the results obtained in foreign trade. In the years 2013-2016, the positive balance of trade in foreign food products was at a level of about EUR 8-9 billion [Kowalski, 2017]. Currently, Poland is ranked eighth among the most important food exporters in the EU. Maintaining of such good results in the subsequent years is, however, uncertain due to the ever-changing conditions of the competition of companies in international markets. The growing labour costs in Poland are a reason for which the possibilities of expansion based on price-cost strategies will be gradually depleted. Maintaining and improving the competitive position of Polish food producers will depend, to a large extent, on the ability to adapt to the evolving reality and to the new environmental requirements resulting from the progressive processes of digitisation. Therefore, a turn towards new digital technologies and the smart manufacturing concept seems to be a necessary step on the path towards strengthening the competitiveness of the Polish food industry.

In the most technologically advanced food sector enterprises, the selected elements of the smart manufacturing concept are already present or are being gradually implemented. They include mainly processes related to monitoring of and improvements in automated production lines, analysis of economic and financial data and other data contained in the enterprise's internal resources (e.g. in ERP systems). However, more advanced analyses using big data, including data collected outside the enterprise's borders, are still rarely applied and used. According to the European Commission's reports on the EU data market, in many Member States the number of enterprises using advanced data analyses is still low. In 2017 in Poland the category of data users included 13 thousand enterprises (slightly more than 2% of all enterprises in Poland). The same year in the United Kingdom, the number of enterprises being data users was 174 thousand (11.2% of all enterprises), in Germany almost 111 thousand (8.2%), and in the Netherlands 26 thousand (12.2%) [The European Data Market Monitoring Tool, 2018].

An indirect indicator of the limited use of advanced data analytics is the percentage of enterprises purchasing cloud computing services. Cloud computing provides the full scalability required in the case of the growing data resources to be analysed. Depending on the sector and industry, this percentage in Poland varies from a few to up to thirty several percent, with the highest percentages applying mainly to sectors with a high degree of concentration (such as pharmaceutical and tobacco sectors). In the case of the food industry, in 2016 cloud computing services were purchased by less than 5% enterprises involved in the production of food products and by less than 7% enterprises producing beverages [Statistical Yearbook of Industry, 2017]. However, it is not clear whether these services are used to create a new value for consumers (new or improved products and services) or only to optimise business processes. The studies carried out by Computerworld in August 2018 show that many enterprises approach digital transformation without a strategic vision of goal [Pietruszyński, 2018a]. More than half (55%) of managers in Poland believe that digitisation of the enterprise requires enormous expenses for infrastructure. As many as 57% of managers do not plan any actions for digital transformation of the enterprise. In the mid-2018, only every tenth company in Poland had a strategic document devoted to strictly digital transformation [Pietruszyński, 2018b].

Building a smart food industry does not imply and does not come down to the adoption and implementation of all digital technologies and solutions available in the market. This process requires preparing a digitisation strategy including both actual problems and needs of individual entities, as well as the account of and economic and social costs and benefits associated with the implementation of technological innovations. The potential of the smart manufacturing concept, supported by advanced data analytics and new digital solutions, can be implemented at various stages and in various areas related to the production process and the wider operation of the company. In the case of food sector enterprises, the benefits of digitisation include, inter alia, the ability to design food products and their packagings in a spirit of consumer-driven design, optimising the process of planning the production types and volumes, automation of production processes and those related to production management, remote monitoring and diagnostics of machinery, and tracking the flow of food products in the supply chain. It is important to stress that the smart manufacturing concept itself in the era of digital breakthrough is changing – new types and kinds of data appear, with the potentially high economic importance and potentially new applications. The selected applications of the smart manufacturing concept in food industry companies based on the currently used and developed technologies are summarised in Table 1.

The functioning of the food industry, based on the paradigm of the smart production and smart supply chains, requires cooperation and involvement of all entities participating in the agri-food chain. It also entails the significant involvement of entities which so far have not been associated with the food production and the agri-food sector – IT companies offering specialised software, high-tech companies specialising in sensing and artificial intelligence technologies, as well as companies offering advanced data analytics services. Large and medium-sized enterprises producing food and beverages have modern machinery parks and software that already enable the implementation of selected elements of the smart manufacturing concept. However, the digital revolution requires the greater opening to new technologies and advanced data analyses.

Table 1. Smart manufacturing in food industry enterprises

Area	Selected methods and solutions	Applications/benefits
Smart design	analyses of data from sales points, analytics of social media, crowdsourcing, 3D modelling and simulations based on digital reflections (digital twins) of products developed based on various formulations/containing various ingredients	adjustment of the composition and packagings of food products to the preferences of specific groups of consumers; identification of potential problems related to the quality of products and their packagings
Production planning	analyses of business processes based on the data from ERP (Enterprise Resource Planning) systems, EAM (Enterprise Asset Management) systems, SCM (Supply Chain Management) systems – *inter alia*, the data on suppliers, data from sales points, financial data; in-depth analyses of the demand for individual groups of food products; economic and market data, data on the weather and climate change	selection of suppliers, increasing the timeliness of raw material supplies, more precise prediction of increases and decreases in the demand for selected food products in specific places and periods of the year, prediction of the adverse impact of external/climate factors on the raw material base, prediction of rises and falls in the prices of raw materials
Automation of processes and optimisation of production	data from sensors and cameras, cognitive sensing technologies, machine learning algorithms, artificial neural networks, platform of the Industrial Internet of Things, tools for the digital twin (CAD – Computer Aided Design, CAM – Computer Assisted Manufacturing, simulation programmes, Product Lifecycle Management programmes – PLM), advanced analyses of production processes	automatic selection of products and raw materials meeting the specific requirements, increasing the efficiency of procedures related to control of safety and quality of food products (inter alia, HACCP procedures), improving parameters of production lines, reduction in costs and improving the productivity
Monitoring of machinery and equipment	data from sensors and cameras, calculation of KPI (Key Performance Indicators), including OEE (Overall Equipment Effectiveness) in real time, early warning systems based on algorithms of decision trees and neural networks	remote diagnostics and maintenance of machinery to prevent malfunctions, predictive maintenance of equipment, improving parameters of machinery, reduction in costs of production, improving the productivity
Smart supply chains	sensors and labels for radio-frequency identification (RFID), systems enabling the integration and exchange of data among various platforms and third party software (open API – Application Programming Interface)	tracking the flow of raw materials and products in the supply chain, insight into the conditions of food transport and storage in real time, food loss and waste reduction

Source: own study.

16.6. Summary and conclusions

The ability to use the opportunities related to digital technologies and big data in the near future will provide the opportunities to maintain and strengthen the competitive position of enterprises in the more and more demanding markets. However, the Polish food industry is just at the beginning of its path to digital transformation. In addition, the prospects for accelerating the necessary transformations are uncertain as the interest of Polish enterprises in digitisation and new business models is still limited. The discussed applications of the smart manufacturing concept show only some opportunities offered by digital technologies, advanced data analytics and artificial intelligence to the food industry. The additional opportunities involve, inter alia, additive manufacturing, which is based on the use of graphics software and 3d printers for the food production. The enormous opportunities associated with various paths and areas of digitisation should, therefore, be a subject of a strategic choice of enterprises thinking of the further development and expansion.

The imperative of digital transformation of the food industry – and more broadly, of the entire agri-food sector – also raises questions about priorities in spending public funds, both from the CAP budget and the EU Structural Funds and from the national budget. At the EU level, new programmes and opportunities to support innovative business solutions are emerging. In the next EU financial perspective for 2021-2027, the pool of funds allocated for strengthening the competitiveness of the European economy is expected to increase significantly. At the same time, in line with the European Commission's proposals, the Member States are to be given more freedom in deciding on the objectives and directions of spending allocated funds. This freedom applies not only to structural and rural development programmes but also to the first pillar of the CAP. It will, therefore, be important to ensure that actions for digital transformation are appropriately supported also in national programmes and strategies dedicated to agriculture and the agri-food sector.

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