Andreász Kosztopulosz – Éva Kuruczleki (eds.) (2020): The Challenges of Analyzing Social and Economic Processes in the 21st Century. University of Szeged Faculty of Economics and Business Administration, Szeged, https://doi.org/10.14232/casep21c.1

Digitalization in the food industry – opportunities and impedimental factors

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The study examines the appearance of Industry 4.0 and digitalization in the food industry that is not typically considered high-tech. Our aim was to point out that Industry 4.0 is also present in the food industry and offers many opportunities in two areas that are a particular focus of this industry: increasing traceability and food safety. During the research, we asked seven companies about their digital development and Industry 4.0 experience. We have explored the factors that drive companies to adopt digital solutions and the technologies that have been applied. Our results show that companies, not consciously moving towards Industry 4.0 but taking advantage of the opportunities offered by digitalization, are making improvements, often with a lack of workforce, eager to reach higher efficiency and thus competitiveness, as well as to serve the company's growth strategy.

Keywords: Industry 4.0, digitalization, food industry, technology

1. Introduction

The world population has tripled since the 1950s, and by July 2019, the Earth's population had already exceeded 7.7 billion. This number, although is slowing, continues to grow and is estimated to exceed 9 billion people worldwide by 2050 (KSH 2018). For this reason, the food supply issue is a constant challenge all over the world, and is one of the central topics of discussion at the 2018 World Forum in Davos. World Economic Forum has taken a global initiative to address the nearly 70% increase in food demand (World Economic Forum 2018). As countries develop and the standard of living increases, the range of foods people consume changes significantly, the energy requirements of the population are much higher, and animal protein intake is increasing (Horn 2013). According to the list of Food Engineering published in 2017, Nestlé (1), Pepsi Co. (2) and AB Inbev (3) are among the world's largest food companies based on sales revenue.

The study examines the appearance of Industry 4.0 and digitalization in a sector that is not typically considered high-tech, the food industry. Although automation has been present in many sub-sectors of the food industry for decades, the achievements of the Fourth Industrial Revolution are being explored mostly by researchers and professionals in the automotive and electronics industries. The study points out that Industry 4.0 is also present in the food industry and offers many opportunities in two areas that are particularly focused in this sector: traceability and food safety. During the research, we interviewed seven companies belonging to the three most important subsectors of the food industry – meat, dairy and pasta industry – about their digital development and their Industry 4.0 experience.

After reviewing the state of the food industry, the study briefly outlines potential industry 4.0 solutions and then deals with the research methodology and process. The results section describes the solutions experienced by each company and concludes with conclusions on the direction and features of the developments.

2. The importance of the food industry

The Hungarian food industry contributed 1.9% of GDP. The gross value added of the sector represented approximately 2.2% of the total national economy (KSH 2017). Generally speaking, the major international successes of the Hungarian food industry in the past have moderated over the past 20–25 years, as their share of world food production has halved (Kapronczai 2016).

Following our accession to the European Union (2004), the results of the food industry in Hungary and abroad showed a different direction. Food exports increased both in volume and due to the weakening HUF exchange rate, thus doubling export sales within the sector (Kürthy–Radóczné 2016a). Domestic sales, on the other hand, declined significantly, and domestic food consumption declined due to low domestic solvency. This kind of success on foreign markets is not so clear given that high value-added products are still not successful abroad.

Regarding foreign trade, food products have grown significantly on both the export and import side, with a total of HUF 900 billion surplus (KSH 2017). This resulted in an almost double-digit increase on the export side compared to previous years. Hungary mainly exports and imports food products to and from certain member states of the European Union, and its main trading partner is Germany in both directions. In addition to the clearly increased foreign trade turnover, Hungary's foreign trade can be described with the same, almost unchanged product structure, both in terms of imports and exports (KSH 2017).

According to Kürthy et al. (2016a), the efficiency of the domestic food industry labour force lags behind that of the EU, which can be explained by the relatively low domestic labour costs, which reduces the incentive for enterprises to move towards technological development due to their extremely high price level.

According to the data of the Central Statistical Office (2017), food industry investments amounted to HUF 198 billion, which meant a 1.6% decrease in the share of the industry in the total national economy. Interestingly, however, the structure of food industry investments has changed, with machinery investment at over 7%, while building investment has declined. Thus, the investment in machinery concerns the 2/3 of the total investment in the food industry.

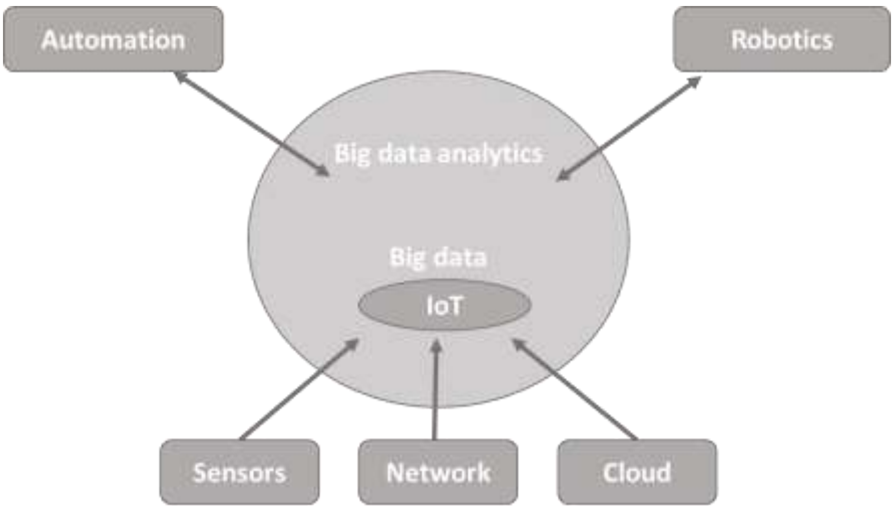
The most important sub-sectors of the food industry are meat, fruit and vegetable processing, dairy processing, bakery and pasta. In a study by Kürthy et al. (2016b), various efficiency and financial indicators for Hungary and a few other EU Member States were examined for each food sub-sector. The results confirmed that in all sub-sector comparisons Hungary is generally characterized by very low net sales, low labour productivity and value added. It is also clear from the domestic companies that the higher export activity significantly improved the profitability and efficiency indicators of the companies.

Overall, the domestic food industry is still lagging far behind the EU member states at the sector level, apart from some unique success stories.

3. Interpretation of Industry 4.0

Industry 4.0 is based on small data production, storage, and transmission devices that observe a product or a production process (sensors) in some way (Lee et al. 2014). This data is transferred to the cloud via an internal or Internet-based network to be analyzed by various software, either automatically or through human work (Rüssmann et al. 2016). Analyzed data is rendered in a user-friendly manner, available to different levels of enterprise decision-makers, complexity and access rights, or to the consumer using the product. The transmission of information is the basis of any decision, approval or intervention, whether automated, on automated production lines or by robots. The most important product and source of Industry 4.0 is data (big data), which is analyzed (big data analytics) and can be used in real time (Wang et al. 2016).

Figure 1 Context of Industry 4.0 technologies analysed in the study



Source: own construction

Industry 4.0 permeates the entire enterprise value chain. However, its scope may extend beyond the boundaries of the company, covering the supply chain or, more broadly, the supply network. It builds on new types of networked technology devices (eg sensors, RFID) and requires new processes (eg data analysis software, cloud, programming) that require new capabilities from the company and may even require the development of new business models. "Industry 4.0 is, therefore, a phenomenon that, by involving new technologies, leveraging the full potential of digitalization, elevates process transparency, integrates value chains and supply chains, and takes customer value creation to the next level" (Nagy 2019, p. 15).

3.1. Industry 4.0 in the food industry

One of the industries most exposed to the variability of consumer demand is the food industry. In addition to consumer trends (healthy lifestyle, aging society, obesity), the food economy also has to cope with pressure from retailers, which means lower prices, higher quality, a constantly renewed range of products and, of course, unquestionable food security. In order to address these challenges from both sides, Industry 4.0 tools can provide many solutions.

While automation and robotization have long been present in many sectors of the food industry (pasta, dairy), others are only partially applicable, and the share of human labour in production is high due to poorly standardized processes (meat industry, bakery products). According to Simutech (2016), machine shutdowns in food processing can cost up to $ 30,000 per hour, so the use of sensors in predictive maintenance to prevent machine shutdowns due to failure can quickly pay off. Processes made transparent with sensors and tracking can help increase energy efficiency, reduce waste and reduce waste. Agility, rapid machine changeover, and the ability to produce smaller series are important considerations when selecting a technology (Carpenter–Wyman 2017).

According to experts (Bibi et al. 2017, Carpenter–Wyman 2017, Bottani–Rizzi 2008), food safety and traceability are clearly areas where Industry 4.0 can greatly support the food industry. Different identification systems can make it possible to trace raw materials incorporated into food from the point of origin to the point of use (Bibi et al. 2017, Carpenter–Wyman 2017).

Researchers see blockchain technology as a tool for food monitoring (Tian 2017, Tse 2017). RFID, barcode, and wireless sensors are well-suited to the food supply chain for transparency and traceability, especially for data collection and transmission. However, you need a medium that makes this information visible. Blockchain raises the level of trust by making the flow of data, goods or money transparent and traceable. The system may be excellent for e.g. the investigation of the cooling chain (Tian 2017). The food industry can therefore take advantage of Industry 4.0 in many ways, thanks to digitalisation. However, some technologies are either expensive, immature, or have little practical experience, so there is no benchmark for learning.

4. Research methodology

We conducted an exploratory study for two reasons. On the one hand, there is little to read about the industry 4.0 experience in the food industry in the academic literature; We reached seven companies from the Hungarian food industry, where we conducted interviews at top management level (managing director, factory director) and carried out on-site monitoring in five cases. The interviewees did not allow us to use the companies' names during the study for confidential reasons. The interviewees were selected in two ways. First of all, we targeted the three largest sectors of the Hungarian food industry: meat processing, dairy industry, pasta production. We were looking for the biggest players in the given sub-sector, and asked for an interview with other players by snowball method. As a result, we managed to reach three dairy farmers, two dairy processors, a meat processor and a pasta factory.

Interviews were usually 90 minutes long each, followed in most cases by a further 60 minutes of site visit and further information.

4.1. Interview data

The following table provides basic information about the interviews that have been conducted.

Table 1 Interview data

Company Data	**„A”**	**„B”**	**„C”**	**„D”**	**„E”**	**„F”**	**„G”**
Sub-sector	pasta prod.	dairy prod.	dairy prod.	dairy prod	dairy process.	dairy process.	meat process.
Location	West Hungary	West Hungary	West Hungary	West Hungary	West Hungary	West Hungary	East Hungary
Inter-viewee	plant manager	site manager	site manager	site manager	plant manager	plant manager	CEO
Date	23.08. 2018	21.02. 2019.	21.01. 2019.	07.02. 2019.	19.09. 2018.	04.04. 2019.	21.08. 2018.

Source: own edition

In 1.5-hour long structured interview with company executives, we talked about the company's Industry 4.0 approach, the digitalisation solutions used, the projects and the directions for development. As all interviewees are top managers of a given company, they are aware of both production and strategic issues and were considered relevant sources of information. The reliability of our research is enhanced by the fact that, although the number of interviews is low, they were conducted with the three largest subsectors of the Hungarian food industry, the bakery and pasta industry, the dairy industry and the meat industry.

5. Interview experiences

In presenting the interview experiences, we will discuss the technologies shown in Figure 1. There are many other technologies that can be linked to Industry 4.0, but these have been found to be dominant in the companies and their application shows correlation.

Sensors

The pasta company (A) tests the weight, moisture content and humidity of the raw material entering the automatic production line with integrated sensors. The consistency of the dough is also controlled and then the temperature of the dryer. The finished dough passes through several checkpoints before and after packing, where any piece of metal found in the production process is screened with a metal detector and the weight and bar code of the packet are also checked. The machines are equipped with preventive maintenance sensors (counting operating hours), any deviation from the norm can be detected immediately and the necessary intervention can be made. In dairy farms, sensors are most important in identifying and tracking animals. Each cattle is provided with RFID transponders, which record all the events of the animal throughout its life, such as birth, ancestors, lactation phase, nutrient mix, treatments, vaccinations (B, C, D companies). Milking equipment also provides data on milking conditions: individual milk yield, milk quality. Companies B and C also use sensors to monitor cattle housing conditions, and ventilators and water chillers are turned on automatically to prevent heat stress, and canopies to protect animals in case of wind. Company D uses an activity monitor to monitor the animals' moving intensity. Company E does not use any sensors. Company F monitors production processes with milk processing sensors to ensure high quality and food safety. At the meat company (G), the purpose of sensory data collection during the construction of the new production line was to monitor the processing process and thereby increase process efficiency.

Network and cloud

Some level of networking can be observed at each of the companies examined. The pasta producer uses its own corporate cloud and load it with data from machines and other systems. At dairy farms, this is mainly limited to identifying and tracking the cattle and recording the related transactions, and to the milking machines transmitting the milking data to the data center. There is no integrated network in dairy B, but monitoring is completed by nutrient planning and monitoring data of the cattle-pen. Data is moving to corporate data warehouses, not yet implemented in the cloud. The Dairy E's network covers the collection of traditional company data, stock management, production planning, financial data, but in the absence of sensors, there is no Industry 4.0-like data collection. Dairy processor F performs extensive data collection, and its machinery equipment is all connected to the corporate cloud. Company G collects data on its meat processing machines, equipment and processes to enhance process efficiency and serve controlling functions.

In our approach, the Internet of Things is based on the three technologies discussed above: sensors that capture product, process and equipment data, connected to the network, and the enterprise data center, whose latest technology solution is the cloud. Not only does the cloud allow to store large amounts of data, but it makes them also accessible to the authorized users. In this sense, IoT exists at the dough maker and dairy processor F, but the germs are also present at dairy B.

Big data and Big data analytics

The problem of large volumes of data was encountered by all the companies investigated. As discussed earlier, not only storage is a major challenge, but also data processing and integration into enterprise information systems. Data can be of real benefit if it is analyzed within a short period of time and can be used in real-time decision-making processes. The pasta company has the highest level of integration and data collection among the respondents, and their challenge is to process the data appropriately. Significant resources are devoted to the development and purchase of data processing software that can be connected to the ERP system. Dairy company B is also making improvements to utilize the resulting data as much as possible to improve animal welfare, optimize production and improve feed efficiency. At companies C, D and E, data processing is low. Company F has an international background, and the parent company expects extensive data collection and analysis, which means that developments in this area are significant and best practices are shared at group level. The meat company is also analyzing the data collected to increase efficiency and increase transparency in the processes.

Automation

In many cases, automation was the basis of production technology in the companies examined, and it was well before the phenomena of Industry 4.0. The pasta producer had already used full automation when investing before 2010, but in many respects, it did outperform it with its 2018 development. Much higher energy efficiency prevails, and sensors have made it possible to achieve even higher levels of optimization, predictive maintenance and transparency. Similarly, automation in milk production and processing is significant in the dairy companies, and the sensitive nature of the product requires closed-loop treatment. This is the case for all three production plants in milking technology and processing. Dairy processor E manufactures hand-made products, where automation is only possible for the minority of the products and significantly raises the quantity produced. According to processor F, automation is the key to high product quality. The meat processor was also able to perform only partial automation, because of the many labor-intensive operations in production.

Robotics

Advanced Industrial Robotics is a branch of robot development that can perform intelligent tasks with sensors and dynamic programming that require more flexibility and precision than traditional robot tasks. Examples of these can already be found in the companies under investigation, but also in cases where, although they have been tried, the nature of the product does not allow it.

The pasta manufacturer uses robots for packaging and serving warehouse processes, which allows handling of manufactured products that would not be possible with human labor. In milk production, a robot is employed in the support process, and in company B, a feed sweeping robot is used. Its task is to dredge the animal's feed at regular intervals, by which the animals reach the food. The dairy processor F employs cooperative robots (cobot) to facilitate manual elements of the production process and robots to perform packaging tasks. In addition to automation, processor E gave up robotization, as it would have had a negative impact on the consistency of its main product. Meat processing robotization efforts could not be realized in the processing process either, because a sophisticated series of human movements would have to be mechanized that could not be realized at a realistic cost.

6. Conclusions

According to Kürthy et al. (2016b), the Hungarian food industry is lagging behind its Western competitors in terms of efficiency and technology, although export activity can significantly boost business revenues. This is also evident in the case of company A, which has reached its capacity limit and is clearly committed to a growth strategy that it plans to build on exports when setting up the new plant. In order to achieve higher efficiency, companies can buy advanced technology and analyse the data it produces to further optimize processes and increase their competitiveness. Our results correspond with Simutech (2016) survey, as interviewees reported serious investments where the focus was not on the cost of technology but on its knowledge, one of the most important of which is predictive maintenance, and they are still working on further exploiting opportunities.

Although corporate interviews report many technological advances only a few of them form systematically structured system (A, partly B, and F). Although these are very large-scale investments, many developments have benefited from national or EU funding, which, according to many interviewees, is a good incentive for digital development (A, B, C, E, G). Another motivating force for development is the shortage of labour in many sectors. In some companies, the intention of automation and robotization was to eliminate the operational risk of losing workforce, or to replace missing workers (partly A, F, G).

However, the food industry companies have a strong interest in Industry 4.0, it is important to mention that there are several factors hindering the development and the investments. Based on the opinions of the interviewees, they feel that the long payback time of the projects, the lacking knowledge and skills of existing workforce to develop, maintain and operate the new technologies and the high labour cost of hiring such employees, as well as the limited tender resources and supporting economic environment are the main reasons behind the postponement of the investements.

In conclusion, we have experienced that there are developments in the food industry that are taking advantage of Industry 4.0 and digitization has begun in many places.

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