Geographia Polonica
2023, Volume 96, Issue 2, pp. 239-257
https://doi.org/10.7163/GPol.0254

INSTITUTE OF GEOGRAPHY AND SPATIAL ORGANIZATION
POLISH ACADEMY OF SCIENCES
www.igipz.pan.pl

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KEY FACTORS AFFECTING INDUSTRY 4.0 ADOPTION: AN EMPIRICAL STUDY IN HUNGARIAN MANUFACTURING COMPANIES

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Abstract

Over the past decade, Industry 4.0 technologies have spread in space and time to varying extents, this being influenced by many factors. Evaluating some of these is the main aim of this study, as they have received little attention so far. Based on the experiences of empirical research (questionnaire survey) carried out in a peripherally located, traditional industrial area of Hungary and using statistical methods, the main significance of the study is that it highlights that sectoral affiliation, the internal organisation of companies and the geographical location of their sites, as well as their social and economic environment, all contribute to the intensity of technological change.

Key words

Industry 4.0 • manufacturing • influencing factors • sectoral affiliation • headquarters-plant relationship • geographical location • social and economic environment • BAZ County • Hungary

Introduction

The concept of Industry 4.0 (I4.0) first arose in Germany in 2011, where it was applied to a strategic incentive programme for improving the competitiveness of industry (Bartodziej, 2017). It has been widely used since then, though it may have had different names in other countries (e.g. "Advanced Manufacturing Partnership" in the USA, "Made in China 2025" in China) (Soomro et al., 2021). Several attempts have been made to define Industry 4.0 (I-SCOOP, 2017; Müller et al., 2018). The earliest definition being given by Kagermann et al. (2013), who stated "In essence, Industry 4.0 will involve the technical integration of CPS into manufacturing and logistics and the use of the Internet of Things and Services in industrial processes. This will have implications for value creation, business models, downstream services and work organisation." Industry 4.0 can also be considered as disruptive changes taking place in the global manufacturing system or as a trend towards a digital revolution in manufacturing (Santos et al., 2017; Bartocci et al., 2018). Its nine core technologies (autonomous robots, simulation, horizontal/vertical integration, Internet of Things, Cybersecurity, The Cloud, additive manufacturing, augmented reality, Big Data), which are the main draws of this industrial revolution, bring radical changes to industrial production (Bouée & Schaible, 2015; Rüßmann et al., 2015). It is not only industry that will undergo huge transformations however, but also society and the whole of the economy (Reischauer, 2018). This is essentially the fourth industrial revolution, which is now in its initial phase (Schwab, 2016).

This fourth industrial revolution is progressing at different rates in space and time and is achieved in various ways, depending on many factors (Rüßmann et al., 2015; Coró & Volpe, 2020; Alayón et al., 2022). Among other things, it depends on the characteristics of a given business or the local social and economic environment. We assume that these factors also affect how and to what extent companies have advanced towards Industry 4.0 maturity. In fact, the main aim of this study is to evaluate three factors based on empirical research (sectoral affiliation, internal organisation of companies, and the social and economic environment related to geographical location). We have investigated how these factors that have received less attention in the past are affecting the spread and use of Industry 4.0 technologies in manufacturing companies located in one of Hungary's traditional heavy industry districts, Borsod-Abaúj-Zemplén County (BAZ County for short). The main reason why we focused on examining these factors is that there is little information available on their impact and significance, although numerous analyses have already been carried out on the factors influencing the spread of Industry 4.0 at the national and global levels (Castelo-Branco et al., 2019; Tay et al., 2021; Elhusseiny & Chrispim, 2022). This is why this study aims to fill this gap, also indicating the novelty of the research.

The further structure of the study: the background of the research based on a systematic literature review paying particular attention to the factors influencing the usage of new technologies is presented in Section 2. The industrial development of the area under investigation is introduced in Section 3. The data and methods are described in Section 4. The results of the empirical research are presented and discussed in six subsections in Section 5, which include the main characteristics of the companies that participated in the survey, the occurrence of Industry 4.0 technologies in the companies, a presentation of the selected factors in the light of the answers and a statistical evaluation of these. Conclusions are given in Section 6, together with recommendations for continuing the research.

Literature review: focusing on factors influencing Industry 4.0

A complete review of the huge number of publications related to Industry 4.0 accessible through WoS and Scopus (about 17-14 thousand) was almost impossible, so we focused mainly on those dealing with manufacturing industry in a single region, as this lay closest to our research topic. These criteria were met by one publication in Web of Science (Thu, 2020) and 43 in the Scopus database. Only a few of these came from Central and Eastern European countries, which suggests that research on Industry 4.0 has only been carried out on a modest scale in this part of the world. Based on the content of the publications, this is mainly linked with technical and technological fields (Nick et al, 2019; Pruskova, 2019; Cieślik, 2021).

According to the literature review one of the main trends in Industry 4.0 research is to investigate the means of introduction of I4.0 and the factors this depends on (Ling et al., 2020; Tortora et al., 2021). Factors influencing the expansion of Industry 4.0 can basically be divided into two main groups: external and internal factors. The formers are those affecting a given business from the outside or surrounding it (e.g. social, economic environment), or in which the business is embedded to some extent. The internal factors are those within a given company. In fact, these constitute the characteristics of a company which can have an impact on the progress of Industry 4.0 (e.g. size, sectoral location, ownership, headquarters-site relationship). The influencing factors can also be grouped according to whether they have a direct or indirect impact. The effect of a given factor on the implementation of Industry 4.0 may be positive, inspiring or negative, restrictive. Identifying the latter is particularly important for a better understanding of the present technological changes in industrial organisations, because without knowing them, the introduction of Industry 4.0 will or may be much slower and less successful. This is probably the reason why exploring these has received special attention in Industry 4.0 research.

One of the most extensive literature-based assessments of the factors affecting the adoption of Industry 4.0 was carried out by Elhusseiny and Chrispim (2022). By analysing 54 studies, they found that there is no clear difference between developed and developing countries, as the same factors are the main barriers to the implementation of Industry 4.0, namely the lack of financial resources, skilled labour, technological knowledge, ICT infrastructure and government support. The difference is only in the degree of the impact of these factors, which can also be grouped as organisational, technological and legal barriers. In general, developing countries are in a worse state as far as these hindrances are concerned, except for a lack of knowledge, which is mentioned more often in developed countries. At the same time, it was found that limiting factors are almost universally present to some extent, and these show many similarities, despite differences of expression (Hamzeh et al., 2018; Ray et al., 2020; Bravi & Murmura, 2021; Tortora et al., 2021). Ghadimi et al. (2022) identified 15 risk factors associated with the implementation of Industry 4.0, which were classified into four main groups (economic, technological, social, external). In a review of the Scopus database, Tay et al. (2021) revealed seven challenges (data management and integration, knowledge-driven progress, technology, security, capital, workforce, education), to which they added three more based on their research, (competitors, culture, mind-set), which can also set serious limits on the Industry 4.0 maturity of companies in Malaysia. In India, the lack of motivation to adopt new technologies was determined as the main barrier (Kumar et al., 2020). And according to an empirical study, in Thailand human capital is the most important factor in the adoption of Industry 4.0 and the biggest challenge to it is the lack of technical skills and expertise (Adebanjo et al., 2021).

The spread and application of Industry 4.0 technologies also depends highly on the major characteristics of companies. One of the most important of these is the size of the firms (Yüksel, 2020). In many cases, whether a company is nationally or internationally owned may also have an impact. This is particularly true in the post-socialist countries, where there are significant differences between national and international companies (e.g. in technical and technological developments, competitiveness, industrial performance, export share and in spatial pattern). Thus it may be supposed that the duality of the Hungarian economy and mainly Hungarian industry is accompanied by an Industry 4.0 divide. Mittal et al. (2018) have compared 17 features of SMEs and MNEs and concluded that they have different opportunities and perspectives for Industry 4.0. Sommer (2015) emphasised back in 2015 that SMEs need to keep pace with technological developments and must not be left behind because the close interconnection of economic actors only allows for a certain degree of technological gap between the two groups.

The adoption of Industry 4.0 varies in different sectors of the economy and, as the geographical distribution of each sector is different, the spatial pattern of Industry 4.0 may also vary from sector to sector. The spread of I4.0 is much faster in industry (including mining and quarrying, manufacturing, electricity, gas, steam and water supply) than in other sectors of the economy (agriculture, service) (Santos et al., 2017; Soomro et al., 2021). However, which new technologies are applied and to what degree in which branches of industry has been less researched. This was confirmed by the results of a search in the Scopus database in 2022 using a combination of the keywords most closely related to the subject of the study (I4.0, country, manufacturing). Only three of the 43 studies discussed Industry 4.0 from the perspective of an industrial branch (metal industry, automotive and electronics) (Zhou et al., 2016; Erbay & Yildirim, 2019; Zinn & Vogel-Heuser, 2019). The car industry is one of the industrial branches where digitalisation and adoption of new technologies are the most advanced (Meil, 2020).

Among the selected papers from the Scopus database, there were very few based on empirical research (Yüksel, 2020; Alayón et al., 2022), although these seemed to be the most interesting from the viewpoint of our research. Their small number may be explained by the difficulties involved in collecting data and information from companies (Tortora et al., 2021). These and the Hungarian publications on I4.0 which have appeared in recent years (e.g. Szalavetz, 2016, 2020; Horváth & Szabó, 2019; Losonci et al., 2019; Nagy et al., 2020;) also indicate that the evaluation of branch affiliation, the position of sites and the social and economic environment of companies has received little attention in the spread of Industry 4.0. Despite this, we assumed that these are important in the successful implementation of Industry 4.0 in a company or in a region. That is why we examined these factors in connection with the progress of I4.0 and proved their importance by means of a survey conducted in northern Hungary.

Industry in the area under investigation

The area studied, BAZ County is located in the north – north-eastern part of Hungary. Its peripheral, semi-peripheral location also contributes to it not being among the most developed areas of the country according to the social and economic indicators. This is reflected in its GDP per capita, which is 68% of the EU-27 average, ranking it 11th out of 19 counties in the country.

The developed industry of BAZ County has a long history and it has undergone significant changes over the centuries. Thanks to the advantageous natural conditions (e.g. ores, energy sources), a significant heavy industry had developed by the beginning of the 20th-century. The most important industries were mining, metallurgy, electricity generation, construction materials and machinery industry, though other branches emerged during the decades of socialism (e.g. textile and wood industry) while the existing ones grew stronger (e.g. chemical industry). By the 1960s, the county had the most developed industry in the country after the capital city, Budapest (Kóródi, 1959). From the 1980s, however, the problems of the one-sided and distorted structure of industry became increasingly evident, but solving them progressed very slowly. After the change of regime, local industry underwent radical changes in organisation, sector, ownership, etc. Deindustrialisation intensified. Many companies were closed down or reorganised and the number of industrial employees fell dramatically from 140,000 to 53,000 between 1985 and 2000. Overall, the position of industry in the region had become very unfavourable by the end of the 20th-century. Later on, however, significant development took place, which was reflected in several indicators of the industry (Tab. 1).

Table 1. Industry of BAZ County in Hungary, 2020

Denomination	Industry of BAZ County	BAZ County's industry	
		[%] of the county's economy	[%] of Hungarian industry
Incorporated enterprises	2,023	11.2	4.7
Firms with less than 50 employees	1,901	10.8	4.7
Firms with 50-250 employees	97	22.1	5.2
Firms with more than 250 employees	25	32.9	4.6
Employees	43,238	28.9	5.7
Companies with foreign interest	103	35.8	4.3
Investments	343,985*	53.2	11.2
Gross Domestic Product/capita	3,336**	-	68.6
Gross value added	709,510*	39.2	7.6

* million HUF, ** thousand HUF.
\- no data.
Source: Central Statistical Office, 2022.

The way out of the deep and protracted structural crisis in the 21st-century was provided by direct foreign investment and re-industrialisation leading to strengthening of the machinery, chemical and food industries. Over the past decade, the industry of the county has developed dynamically and become increasingly integrated into the global economy. Nowadays BAZ County possesses a particularly open economic structure, also demonstrating a high level of spatial and sectoral concentration. These attributes cause the whole regional economy to be more exposed to and dependent on external factors and trends. The traditional industrial capacities and branches coexist with the newly settled, emerging activities. According to the cumulative ranking of several industrial indicators, the county scores high in the ranking of counties (fourth) (Kiss & Nedelka, 2020). It is therefore, the county with the most significant industry in the eastern half of Hungary, which is why it was selected as an area for study. The other reason was that, it is a peripheral area, so it is also possible to explore how digitalisation and the spread of new technologies are progressing and what specific characteristics they have in the industry of such an area.

Data and methods

In the course of the research, the necessary data were provided by statistical publications and company databases (Creditonline, Opten). But since statistical data were not available on the effects of the various factors, and observations on these in the literature were also limited, we conducted a questionnaire survey of manufacturing companies to assess these factors and to achieve the goal we had set. This information can only be collected from industrial companies, as the extent of the application of Industry 4.0 technologies within a company can be judged most accurately by practitioners.

For the online questionnaire, the Survivo service system was used. The standard questionnaires contained a total of 28 questions related to three sets of issues: (i) the main characteristics of the company, (ii) technologies of Industry 4.0 in the companies, and (iii) factors influencing their application. The questions were closed- or open-ended. There were also questions requiring respondents to choose between two extremes by also indicating the degree of difference between the two opposing views.

When selecting the companies to be included in the survey, we tried to take a number of criteria into consideration: larger number of employees, foreign ownership, organisational form (joint stock company), certain branches (machinery industry, metalworking, chemicals, food industry), because based partly on previous studies we assumed that the adoption of Industry 4.0 technologies is more advanced in the firms with these characteristics (Rüßmann et al., 2015; Horváth & Szabó, 2019; Losonci et al., 2019). In the end, however, the sample of respondents was a random selection from the original sample, though this did not result in significant disproportionality in the characteristics of the respondents.

The intension was to include a total of 50 manufacturing companies in the empirical study, representing 46% of the manufacturing companies in the county with more than 50 employees. The questionnaire survey was started in the autumn of 2020. Due to the very slow response rate, two reminders were sent by email and a telephone call was also made to companies in early 2021 to ask them to complete the questionnaires. Thanks to the repeated requests, 27 companies completed the questionnaires (54%), though the response rates to each question varied. The companies participating in the survey were numbered from 1 to 27 and they are referred to as such in the text (R12), since their data were provided confidentially and can only be referenced in a non-identifiable way. What can be stated, however, is that the Hungarian subsidiaries of several well-known foreign companies (e.g. Bosch, Nestlé, Fux, Joyson, Ten Pao, Shinwa, GS Yuasa) participated in the empirical research.

Since the responding companies represented a quarter of the large and medium-sized manufacturing companies in the county (60% of large and 14% of medium-sized companies) and because they are the main companies in the area, their answers can be used to create an important basis for a better understanding of the diffusion of Industry 4.0 in the context of various influencing factors in a peripheral area.

The data extracted from the survey and the number of companies included in the investigation determined the statistical method used for processing, which was cross-tabulation analysis. Both the factors influencing the implementation of Industry 4.0 and the technologies of I4.0 were considered as category variables, thus the Pearson's chi-square (χ^2) test was used to examine the relationships among the data obtained from the surveys. This treatment is suitable for examining variables measured on a nominal scale and can be considered a robust test, because it is less exposed to the conditions of the test. During the procedure, the frequency of occurrence of the I4.0 category variables was checked if it differed significantly ($p < 0.05$) for the enterprises with different characteristics (e.g. year of foundation, number of employees, sales revenue, branch, location). The Cramer's association index, measured on a scale of 0 to 1, was calculated to examine the effects of influencing factors.

Based on the processing of the data using statistical methods, the results were evaluated in the fourth stage of the research process.

Results and discussion

Companies in the survey

More than half of the manufacturing enterprises were established in the 1990s during the period of deindustrialisation (n = 27) and 26% were founded in the past decade as the result of the post-millennium reindustrialisation wave (Tab. 2).

The majority of owners were foreigners (55%), mainly from Western countries (e.g. Belgium, the Netherlands, Luxembourg, Germany, Switzerland). Asian owners included investors from Hong Kong, Singapore and Japan. Most of the companies represented the machinery industry, followed by the food industry (26%), metals (22%) and chemicals (15%). The companies belonging to the category of large and medium-sized enterprises had high annual net sales. Almost all of the enterprises had both their headquarters and their plant(s) in the county, mainly in the county seat of Miskolc, indicating a strong spatial concentration.

Table 2. Major characteristics of the manufacturing companies surveyed in Hungary, 2021

Denomination	Year of foundation			Number of employees		Owner		Branch of manufacturing				Return from sales [in HUF*]			
	1990-2000	2001-2010	2011-	50-250	250 -	Hungarian	foreign	machinery industry	metal industry	chemicals	food industry	less than 650 million	650 million-3.25 billion	3.25-16.25 billion	over 16.25 billion
Number of companies surveyed	14	6	7	12	15	12	15	10	6	4	7	4	2	7	14

* HUF 40,000 = approx. EUR 100
Source: based on the survey in BAZ County edited by authors, 2022.

Industry 4.0 maturity

The term Industry 4.0 was not unfamiliar to respondents at the time of the survey, as most of them had heard of it. 44% had been aware of it for at least 4-6 years, and this is essentially in harmony with the spread of the term in international practice (Schwab, 2016).

Just like in other countries, the number of businesses with Industry 4.0 technologies varies, influenced to differing degrees by a wide range of factors (Kopp & Basl, 2017; Królikowski et al., 2021). In general, smaller companies tend to have fewer new technologies than larger ones, which use a much wider range of them. Some research suggests that the technological level of products has a greater impact on the adoption of Industry 4.0 than the size of the company (Mittal et al., 2018) (Tab. 3).

The most commonly used I4.0 technologies are cybersecurity and cloud technologies, which matches the observations of other studies (Rüßmann et al., 2015; Yüksel, 2020). These are very important for businesses, regardless of size or sectoral affiliation. In 92% of enterprises, data are stored on their own server parks, which are protected by applications and services providing a high level of cybersecurity. Data and information on the different phases of production and on machines are usually provided by sensors, which are very widespread and present in 74% of firms. The flow of data is ensured by the intranet for security reasons, although 4G-based communication is also used by a third of the companies. Cloud technology, used by more than half of the enterprises, is particularly common in the food and metal industries. The collection of Big Data from various sources is mainly a specific feature of companies in the machinery and food industries. It is not uncommon for firms to use external service providers to analyse the data. Robots are mainly used by food companies. 3D printing is particularly useful for the machinery industry, e.g. for prototyping or custom-made products, and it is therefore very popular among these companies. This industry is also the one that uses simulation the most in order to model and optimise production.

New technologies that are less common are augmented reality (AR) and vertical/horizontal integration, though four companies are planning to use these in the future. The Internet of Things was found in 30% of the companies, mostly in the food industry. For example, for a food company (R20), this means that to their machines can also be connected from Germany and the production processes or company operations can be monitored even from a distance.

Firms that were founded in the decade following the turn of the millennium, those with a larger number of employees, those with significant income and those belonging to the food industry have the highest number of new technologies on average. A significant difference is that the use of I4.0 core

Table 3. Industry 4.0 technologies in the manufacturing companies surveyed in Hungary, 2021

Denomination	Machinery industry		Metal industry	Chemicals		Food industry		Proportion of firms having I4.0 technology [%]
	medium-sized firm	large firm	medium-sized firm	medium-sized firm	large firm	medium-sized firm	large firm	
1. Big Data	1	1	2	-	2	-	4	37
2. Cloud-system	2	2	5	-	-	1	5	55
3. Cybersecurity	3	4	5	1	3	1	5	81
4. Internet of Things (IoT)	-	1	2	-	-	1	4	30
5. Augmented reality	-	-	-	-	1	-	3	15
6. Autonomous robots	-	-	1	-	1	1	4	26
7. Simulation	-	5	2	-	2	1	-	37
8. Vertical/horizontal integration	-	1	-	-	1	-	-	7
9. Additive manufacturing	-	4	1	-	2	1	-	30
10. Server park	3	5	6	-	-	-	-	92
11. Sensor	3	5	5	-	-	-	-	74
12. 4G/wireless Internet	-	1	2	-	-	-	-	33
Total number of technologies	12	29	31	1	12	6	25	116
Average (1-9 core technologies)	1.5	3.0	3.0	1.0	4.0	3.0	5.0	3.2
Average (1-12 technologies)	3.0	4.8	5.2	2.0	6.0	5.0	7.6	5.2

- not available.
Source: based on the survey in BAZ County edited by authors, 2022.

technologies is even less widespread than sensors or server parks, for instance (Tab. 4).

Only a few enterprises, barely a fifth of all those surveyed, and mainly in the food industry indicated that they were doing independent research in connection with I4.0 and that they had introduced innovations. For example, hardware development for the introduction of AR is carried out by one of the companies in the machinery industry (R17). The Czech-owned metals company (R26) has introduced a complex production monitoring system for which the software was developed by the company itself. More than half of the companies also lay great stress on the active participation of their employees in professional forums (e.g. conferences, workshops) that promote digitalisation of the company and the application of new technologies. At the same time, the majority of the companies belonging to the same sector replied that there was no cooperation among them in the application of I4.0.

For most companies, manufacturing (81%) and warehousing (75%) are the two areas where digitalisation is the most advanced. Finance is in third place (63%), followed by sales (37%) and communications (31%). The areas of application for new technologies within a company are influenced by a number of factors, these include: "budgets, institutional and managerial differences within the group" (R16, machinery industry company). "Lack of skills is also a barrier, and older workers (mainly manual labourers) are reluctant to use new technologies." (R26, metals company). "Lack of knowledge, lack of management commitment and tight financial resources are the main barriers to the diffusion of new technologies to other functional areas." (R21, food industry company). Another important influence mentioned was that "...digital development has a long payback period." (R20, food industry company). There was also an opinion that above a certain company size (800-1000 employees) the

Table 4. Industry 4.0 by the characteristics of the manufacturing companies surveyed in Hungary, 2021

Denomination	Year of foundation			Number of employees		Owner		Branch of manufacturing				Return from sales [in HUF*]			
	1990-2000	2001-2010	2011-	50-250	250 -	Hungarian	foreign	machinery industry	metal industry	chemicals	food industry	less than 650 million	650 million- -3.25 billion	3.25- -16.25 billion	over 16.25 billion
Number of companies with their own research and innovations in connection with Industry 4.0	2	2	1	2	3	2	3	1	1	0	3	0	0	0	5
Number of companies where employees actively participate in various events related to Industry 4.0	9	1	5	8	7	9	6	4	4	2	5	3	1	3	8
Number of companies involved in cooperation in I4.0 with firms of the given branch	3	1	2	3	3	3	3	3	0	1	2	2	0	0	4
Average (1-9 core technologies)	3.4	3.8	2.5	2.3	3.9	3.1	3.3	3.0	3.0	3.3	3.6	1.8	2.5	2.1	4.2
Average (1-12 technologies)	5.4	6.4	4.1	4.0	6.1	5.3	5.1	4.8	5.2	5.0	5.7	2.8	5.0	4.1	6.4

* HUF 40,000 = approx. EUR 100
Source: based on the survey in BAZ County edited by authors, 2022.

planning process and implementation of the development can be much slower and less efficient (R18, chemical company).

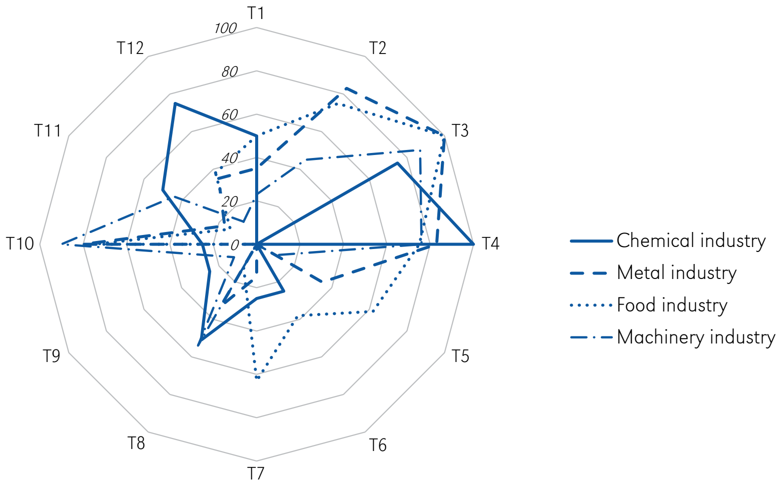
Regardless of branch affiliation, there was full agreement that the use of digital technologies is the key to the development and renewal of industry. This was also reflected by the average score (4.6 out of 5). In contrast, companies considered digital transformation to be less important for enhancing national and international competitiveness, with an average score of only 4.2.

Industry branch affiliation

The survey confirmed that companies belonging to different industries apply new technologies to differing degrees. The respondents agreed that branch affiliation also influences what kind of new technologies a company uses (Fig. 1).

The extent of branch influence can be assessed by the average of the points (3.7) given from 1 to 5, where 1 represents the smallest influence and 5 represents the strongest influence. On average, companies rated the branch impact as stronger than medium, i.e. it matters which branch the company belongs to. Of the two extreme opinions, there were companies that emphasised the dominance of the sectoral classification and gave 5 points (R26, metals company). At the other extreme, for the purposes of I4.0, relationships within the production chain are more important than sectoral affiliation (R2, chemical company). In general, food and machinery industrial companies attributed greater importance to branch influence and assigned more points (4 or 5).

In order to better assess the impact of industrial branch affiliation, we also asked firms which industrial branches are considered the most advanced in the application of I4.0 in general. Based on their replies the following order has been determined: electronics (59%), pharmacy (53%), vehicle production



T1 – Big Data; T2 – Cloud-system; T3 – Server park;
T4 – Cybersecurity; T5 – Internet of Things (IoT); T6 – Augmented reality;
T7 – Autonomous robots; T8 – Simulation; T9 – Vertical/horizontal integration;
T10 – Sensor; T11 – Additive manufacturing (3D); T12 – 4G/wireless Internet.

Figure 1. Industry 4.0 technologies by branches in manufacturing companies surveyed in BAZ county, Hungary, 2021

Source: based on the survey in BAZ County edited by authors, 2022.

(41%), machine and machine equipment production (35%). Light industry and the metal industry were those branches where new technologies are the least used. Almost 60% of the companies assessed that their branch is not at the forefront in I4.0 scoring (at 3 on a scale of 1 to 5). These are rather in the midfield.

The differences between branches can be traced back to various reasons, of which branch requirements and standards are the most important, as well as the long-term practices of each branch. The speed of adoption may also depend on whether we are looking at a modern industry (e.g. electronics) or a traditional one (e.g. metals industry), because in the former the spread of new technologies is usually faster. However, it is also important to mention that there can be significant differences in the application of new technologies even within a branch, depending, for instance, on what the main function of the company is.

Internal organisation: headquarters-plant status

In I4.0 applications there are significant differences among companies depending on the site status. This may manifest between the plants or between the headquarters and the plant(s) of a company (Tab. 5).

According to the survey, twelve of the companies (44%) had one or more plants. The average number of plants per firm is 2.3. The total of nearly 30 plants was primarily connected with food, machinery industry and chemical companies. 63% of the companies' headquarters are located in Miskolc, but the average value of I4.0 is more favourable outside the county seat, in other settlements of the county. This can be explained by the fact that the newer, larger, more modern and mostly foreign-owned factories could only settle outside the county seat, in other, smaller settlements of the county. The main reason for this is that in the town there were no free (green) areas available for new firms

Table 5. Industry 4.0 in the headquarters and plants of the companies surveyed in Hungary, 2021

Denomination	Location of headquarters		Companies	
	in Miskolc, the county seat	in another settlement in the county	with one or more plants	without any plants
Number of firms	17	10	12	15
Average (1-9 core technologies)	2.9	3.7	3.7	2.8
Average (1-12 technologies)	4.8	5.9	5.9	4.6

Source: based on the survey in BAZ County edited by authors, 2022.

and the reutilisation of old brownfield industrial areas has not been possible for various reasons (mostly high costs) (Kiss, 2004). The results show that the spread of new technologies is more advanced among companies with plants.

National and foreign companies with plants emphasised that the progress of I4.0 is influenced to the greatest extent by the company's headquarters. For example, according to the manager of the Japanese machinery industry company (R9), the influence of the parent company prevails by centrally defining the guidelines and budgets for applying Industry 4.0. The role and influence of the parent company may also be manifested in the fact that it sets a good example in digital transformation, since this process is generally more advanced in the headquarters (R26, metals company). At the same time, the head of a Hong Kong electronics company (R19) also noted that since wage costs are lower in Hungary, replacing the workforce (e.g. with robots) was not a matter of urgency for the corporate headquarters. In addition, the strong influence of the parent company is confirmed by the reply of a metals company in Singapore (R22). Given that its factory in Hungary is its smallest plant, new technologies are introduced and tested here. If everything works well, then the "best practices" acquired here will be transferred to all its other factories. In contrast to the above, there is also an example of a "bottom-up" initiative from a plant with the approval of the headquarters. The idea of implementing I4.0 in at least one area of the plant came from the Hungarian site of a German parent company, because for lack of it, production at the plant is not economical. Finally, with the support of the headquarters, some of the plant's 120 production lines now employ I4.0, which was introduced to a special product portfolio (R24, machinery industry company).

Based on the survey, the differences in the application of I4.0 within a company with one or more plants can be explained by several factors, but the main reasons are differences in management, ICT and employees' qualifications, as well as difficult and limited information and data exchange. According to other research, the most important of these are the workforce and ICT infrastructure (Hamzeh et al., 2018; Tay et al., 2021).

Geographical location and socio-economic environment

The influence of geographical location and the on-site environment on the usage of I4.0 by companies was rated at 3.2 on average by the respondents. Metals and chemical companies scored 3 points or less, while machinery and food industry companies assigned 4 points or more on a scale of 1 to 5, meaning that the latter attributed a stronger influence to the local social and economic environment.

Of the local conditions that can facilitate Industry 4.0, regardless of the industrial branch, the quality of the workforce was considered the most important by the respondents (60%). This was followed by the development of local IC infrastructure (53%), the nature of the corporate culture (46%)

and the innovative environment (40%). Industrial branch differences can also be identified in the assessment of the last three factors, because the first factor was mainly identified by metals companies, the second by food industry companies and the third by machinery industry companies. On the other hand, the local institutional and social environment was given much less importance. It is probably because they are mostly larger firms. It is mainly smaller firms that are most impacted by location-based influence (Mittal et al., 2018; Tay et al., 2021).

Various governmental financing and tax initiatives can promote the spread of I4.0 (Turkyilmaz et al., 2021). Capital investments in I4.0 and advanced digital solutions are extremely important for (manufacturing) companies, because their digital maturity is a relevant precondition for their longer-term survival (Szalavetz, 2020). As in other studies, the majority of respondents (80%) believe that the spread of I4.0 is mainly hindered by a lack of financial resources. The companies surveyed made this claim, although half of them received national support for acquiring new technologies. For example, one of the large machinery industry companies (R8) used part of support received to buy cobots. It was also a large machinery industry company (R5) which received international (EU or other foreign) support. Mostly metals companies did not receive financial support. In addition to the lack of resources, the other key factor that can hinder the implementation of Industry 4.0 the most (53%) is a lack of expertise (Tab. 6).

Considering the above, firms basically regarded local ICT service providers (73%) and various educational institutions (60%) as external factors that could best help the introduction of I4.0. More than a quarter of the respondents also considered the stimulating and supportive impact of competitors (mainly food industry companies) and suppliers (especially metals companies) to be important. Furthermore, the same number mentioned the importance of customers as other factors, whose increasing quality needs and suggestions can also contribute to the application of new technologies.

Statistical test for the survey data

During our analysis, the requirement that the variables must be independent was fulfilled. With the adoption of the chi-square test, we checked the assumption < null hypothesis (H0) > that there is no correlation between the variables examined, i.e. the factors influencing the implementation of Industry 4.0. In such case that the critical significance level (p value) associated with the chi-square value was lower than 5%, the null hypothesis (H0) was rejected with the conclusion that the company's given characteristic has a significant

Table 6. Factors influencing Industry 4.0 in the manufacturing companies surveyed in Hungary, 2021

Factors facilitating Industry 4.0	Percentage of replies (level of agreement) [%]	Factors hindering Industry 4.0	Percentage of replies (level of agreement) [%]
Quality of labour force	60	Limited financial sources	80
Local ICT infrastructure	53	Lack of special knowledge	53
Company culture	46	Lack of commitment	27
Innovative environment	40	Lack of support within the organisation/enterprise	27
Local social environment	13	Lack of technology	20
Local institutional environment	7	Unmotivated labour force	20
Others	7	Lack of experience	20
		Others	-

Source: based on the survey in BAZ County edited by authors, 2022.

effect on the frequency of occurrence of the given I4.0 technology. The critical significance value (p value) was derived from comparing the theoretical value of the chi-square distribution with the chi-square value calculated from the survey data. Cramer's association indicators express the relationship between the factor influencing the realisation of the selected I4.0 (company attribute) and the given technology from I4.0. For example, a value of 0.542 indicates a moderately strong relationship (Tab. 7).

During the statistical analysis, the variable describing the owner (foreign or domestic) was the only one for which none of the I4.0 attributes indicated a tendentious deviation, so no verified statement could be made. Regarding the year of establishment and the number of locations (one or more), only one variable indicated a significant difference in each case. For the other company characteristics, it is possible to separate companies on the basis of two or more I4.0 variables.

I4.0 properties (category variables) can be divided into two distinct groups. One includes those technologies which do not differentiate the companies significantly (Server park, Cyber security, Sensors, Cloud-system), as these are generally widespread use by businesses. The availability of other technologies (Big Data, Internet of Things, AR, Autonomous robots, Simulation, 3D printing, Wireless internet/4G, Vertical/horizontal integrations) in companies demonstrates considerable differences, as the introduction of this group of technologies by entrepreneurs is still in progress.

When the companies were examined by the number of employees using all four significant variables, it was confirmed that the I4.0 technology is typical for large companies and less so for medium-sized ones. The technological portfolios of the latter are more

Table 7. Attribute table of Chi-square test values

Industry 4.0 technology	Selected factor	Chi-square test value	Significance (p)	Cramer's value
Additive manufacturing	Size (Number of employees)	4.7	0.030	0.417
Autonomous robots	Size (Level of revenue)	4.3	0.037	0.401
	Sectoral affiliation (4 branches)	9.0	0.029	0.577
	Sectoral affiliation (2 branches)	7.9	0.005	0.542
	Location (HQ status)	4.8	0.029	0.421
Big Data	Foundation (Year)	6.0	0.049	0.473
	Size (Number of employees)	3.8	0.050	0.377
	Location (HQ status)	4.2	0.040	0.394
Cloud-system	Sectoral affiliation (4 branches)	8.6	0.036	0.563
Internet of Things (IoT)	Size (Level of revenue)	10.6	0.014	0.625
	Sectoral affiliation (2 branches)	5.5	0.019	0.458
	Sectoral affiliation (4 branches)	7.4	0.062	0.522
Augmented Reality (AR)	Size (Level of revenue)	4.4	0.037	0.402
	Sectoral affiliation (2 branches)	4.6	0.031	0.414
4G/Wireless Internet	Location (HQ status)	5.1	0.024	0.434
Sensors	Sectoral affiliation (4 branches)	6.3	0.044	0.481
Simulation	Size (Number of employees)	3.8	0.050	0.377

Source: based on the survey in BAZ County edited by authors, 2022.

limited and partial, as they are lacking in components like AR, robots and simulations. In contrast, the large enterprises (in terms of employees and revenue) have a greater variety of I4.0 technologies at their disposal. More than half of the businesses with high sales have already installed IoT, AR and autonomous robot technologies.

Evaluation of the sectoral distribution of the companies indicated several novel correlations. The pioneering role of the food industry in the field of I4.0 has been confirmed, the actors in the sector being open to I4.0 technologies and the extensive use of digital technology. The metal industry has a significantly lower level of technology intensity. The other branches (machinery and chemical industries) use a large number of Industry 4.0 technologies, but the pattern for these companies shows fragmentation and heterogeneity in the field of I4.0, including extreme and totally opposite cases.

Regarding the geographical location of the companies in the Miskolc agglomeration or in other parts of the county, no advantage of location in the agglomeration was confirmed by the analysis. Being located geographically far from the county seat and its agglomeration did not cause significant disadvantage for companies in terms of I4.0 development.

Conclusion

The study examines the extent to which Industry 4.0 has advanced in companies located in a highly industrialised county in Hungary and the factors influencing its adoption paying particular attention to some previously less examined elements. The relevant literature and the findings of the survey show that economic actors are involved to differing degrees and are at different stages in the application of I4.0 technologies, since this depends on a complex interaction of many factors (Bravi & Murmura, 2021; Elhusseiny & Crispim, 2022). Thus the Industry 4.0 development paths of companies differ from one another.

Although various earlier studies have identified a number of factors that influence the use of I4.0 to a greater or lesser extent, evaluation of the factors we selected (industry affiliation, headquarters-site status, geographical location and social-economic environment) has not yet received particular attention. These influencing factors can be defined as new categories leading to new results compared with previous research (Geissbauer et al., 2016; Tay et al., 2021; Alayón et al., 2022; Ghadimi et al., 2022).

The survey data were processed and analysed, straightforward descriptive statistical methods and Pearson's chi-square test were applied and confirmed. The calculations are significant and meaningful, leading to appropriate conclusions for understanding the important role of branch affiliations, organisational structures and geographic locations. In the application of new technologies there may be significant differences in Industry 4.0 maturity depending on the branch affiliation. The status and quality of relations between the headquarters and plant(s), the division of labour within the internal organisation of a company and the function of sites can greatly influence the spread of Industry 4.0. The location of different sites along the global value chain also affects the progress of I4.0 and digitalisation (Meil, 2020). The research also confirmed that the headquarters of companies play a decisive role in which plant technological development takes place and to what extent. The occurrence of new technologies was more frequent in the sites located outside the town of Miskolc. The geographical location of a company and the local social and economic environment, as well as the institutional background, i.e. factors known as location-based influences, were also somewhat significant in the implementation of I4.0, even if the relations between companies and local institutions are usually occasional and of low-intensity.

The empirical results have proved that there are significant differences in the I4.0 maturity of manufacturing companies, and new technologies are not equally widespread in firms. Industry 4.0 is the most advanced in the companies which are larger, foreign-owned, represent the food industry, have plants, and were founded after the turn of the millennium. The company characteristics as a starting condition can have a relevant impact on the adoption of I4.0 technologies (Šlander & Wostner, 2019). The duality or the division of manufacturing companies by their characteristics also contributes to the "digital divide" in the application of I4.0 technologies (Alayón et al., 2022). Even although "size is determinative", the nine core technologies are less widespread even in larger firms, because their average score is quite small. This also means that we are at the beginning of this technological transformation.

Foreign-owned companies are ahead in Industry 4.0 and this is due to the fact that they are more open and more exposed to global standards and expectations. This is in harmony with the findings from other survey carried out in Italy (Coró & Volpe, 2020). These sites can contribute to the transfer of knowledge on corporate digitalisation and technology from the global and regional to the local level and vice versa as important "bridge builders". The significance of each level shows a certain asymmetry depending on the size and activity of companies, because the global level is more important for global companies, whilst local embeddedness is stronger in medium-sized firms.

Overall, it can be concluded that although the concept of Industry 4.0 is well-known to companies in the area studied, most of them are in the initial phase in the application of new technologies and this is reflected in the relatively low values of I4.0. But there are also companies where technology change is more advanced. Many of these are companies with foreign interest and they often occur in an isolated manner, "like islands" which can also be interpreted as a symptom of the peripheral character of the area. These contribute significantly to the spread of I4.0, which usually take place more rapidly than in domestic companies. The application of new technologies is influenced by a very complex set of factors, among which the branch affiliation, the site status and the nature of the social and economic environment surrounding the companies are important, but not decisive factors. The branch affiliation seems to be a factor with a more powerful effect on I4.0 than the geographical location or the distance from the county seat. The large companies have more resources to finance the creation of I4.0 technology systems, though their extended size might reduce the speed of the adoption process. The empirical findings indicated some differences in I4.0 depending on the two main types of enterprise management (domestic or multinational/foreign), but no statistical evidence has been found on this divide. Further investigations are therefore needed in order to explore the mechanisms acting in this field and the real role of management.

The main contribution of this study involving new results is that it has identified three factors that also affect the spatial progress and intensity of Industry 4.0. The extent of their influence was also determined. Our research, which provides more accurate knowledge on the factors influencing Industry 4.0, thus contributes to a better understanding of its expansion. These experiences and company reactions can also serve as a basis for other companies to be able to handle new technological challenges more effectively. BAZ County is also a good example of how a former heavy industry district can adjust to I4.0, in which the "path dependency" of its development is also reflected. Although each industrial company is following different strategies and development paths in relation to I4.0 technologies, together they are significantly promoting the digitalisation of local industry and the development of the whole region.

The limitations of the study are primarily related to the empirical research, because the proportion of respondents is relatively low and their make-up was formed randomly, which may also have some influence on the results obtained. The main directions for continuation of the research may be the expansion and deepening of empirical research not only in space, but also in terms of test methods and investigation criteria (e.g. economic crisis, pandemic situation), because of the global challenges emerging in recent years.

The results of the research may be important for professionals and companies, as experiences indicate that no comprehensive knowledge of these topics is available to them. In a wider context, the lessons of the survey may contribute to a better interpretation of the application of Industry 4.0 technologies, thereby promoting more stable companies, and better decision making on economic policy and regional development.

Acknowledgements

This study is part of the project supported by the National Research, Development and Innovation Office. Project number: K 125 091.

Editors' note:
Unless otherwise stated, the sources of tables and figures are the authors', on the basis of their own research.

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Article first received • October 2022
Article accepted • May 2023