

Final report of the K 125091 project

Theme: New trends in the spatial pattern of Hungarian industry in connection with the fourth industrial revolution

In the last decade, which can be considered the early stage of the fourth industrial revolution, Hungarian industry and its territorial processes underwent various changes as a result of the spread of Industry 4.0 technologies. We approached the realization of the set goals in a complex way. This meant that we examined the Hungarian industry and its spatial processes from different aspects and used different methods (quantitative, qualitative) at different territorial levels in order to reveal the new trends as precisely as possible. It should also be emphasized that the results of the research carried out in several directions can be considered completely new, since the relationship between Hungarian industry and Industry 4.0 has not been investigated yet in such contexts and in such depth in Hungary.

Due to the pioneering nature of the research, several difficulties arose in the initial phase. One of the most important of these is that the various data and information sources required for the investigation were not yet available in Hungary. At that time, the industrial application of Industry 4.0 technologies was also very modest. The domestic literature background was also scarce. Hungarian Central Statistical Office provided the first data on new technologies a few years late, but only at macro and regional levels. Since no data was available on the spread of Industry 4.0 technologies in companies, larger emphasis had to be placed on empirical research than planned, which was much more time-consuming and costly. This was also related to the reluctance of industrial companies to provide any information. Thus, empirical research faced continuous difficulties.

The other main problem was caused by the fact that the contributing senior researcher retired in the third year of the research. As a consequence, the PI had to ask more external contributors to carry out the various tasks, and that also required a lot of time. It was also unfavourable that only few students undertook to collect data from industrial companies, because the companies were not generally cooperative. The Covid-19 pandemic, as an extraordinary event, has also slowed down the research, which has recently been accompanied by new challenges (e.g. war, energy crisis).

On the whole, despite all these difficulties, the originally set goals were basically achieved within the framework of the 'flagship research', and in some respects they were even exceeded. The results of the different research directions (ICT infrastructural supply, factors affecting the spread of new technologies, employment, health industry, etc.) have already been published in some form, which are the following:

1. Based on the static and dynamic analysis of Industry 4.0 (I4.0) publications published since 2011, found in the two most important literature databases (WoS, Scopus), we revealed the spatial pattern of the fourth industrial revolution (4IF) on a global level. The number of these publications only started to grow faster after 2017. Since then, their number has almost tripled. The countries with more publications are usually more advanced in the adoption of I4.0 technologies. These are mostly developed countries (e.g. Italy, Germany, UK, USA, Spain, France), where hundreds of publications have been published in connection with the 4IF. At

the same time, the number of publications is much smaller in less developed countries, which is influenced by many factors.

2. Industrial revolutions and the development of telecommunications have been closely intertwined in recent centuries. The fusion of informatics and telecommunications was realized during the third industrial revolution. The relationship between industrial production and ICT is becoming closer during the period of the fourth industrial revolution, which brings about revolutionary changes in industry and regional development. We compared the geographical features of the third and fourth industrial revolutions from four points of view (location choice, employment, settlement development, regional development). We pointed out that through the development of ICT, new opportunities can open up for backward, peripheral areas, because these areas can also be involved in industrial production. Industrial activity can therefore also appear in areas where it was not typical before.

3. Comparing the spatial appearance of old and new info-communication technologies with that of industry, we found that the geography of old ICT follows that of industry less, whereas the occurrence of new ICT is much more closely related to industry, especially in counties with more developed industry. The data of the indicators were provided by the official statistical publications at different times, and we used cluster and factor analysis in addition to the cartographic method. The fact that the old and the new ICT are more separated in space can be traced back to a number of factors (e.g. different social and economic environment, infrastructural development, differences in human resources). Although the industry plays an important role in the dissemination of new IC technologies, other factors are also necessary (e.g. social, economic factors) which are not sufficient in themselves. The spatial distribution of ICT shows a distinct north-south digital divide. At the same time, the former north-south division is less prevalent in industry today, and new trends are beginning to appear in the geography of Hungarian industry.

4. One of the most widespread new technologies is (autonomous) robots, the industrial geography study of which was missing from the domestic literature. In order to explore the geography of robotization in Hungarian industry and its relationship with the geographical location of businesses, a database of companies that use robots had to be created. We collected data on a total of about 600 companies (year of foundation, owner, size, sector affiliation, location, etc.) and processed them using different methods (cross-board analysis, chi-square probe, ETA-test, ANNOVA-test). We found that the occurrence of robots is primarily related to large companies and some industries, and they are highly concentrated in space. This follows international trends and the (dual) spatial structure of Hungarian industry.

5. In one of the country's traditional industrial districts (BAZ county), we examined the adoption of Industry 4.0 technologies in some more important industries (machinery industry, metal industry, chemical industry, food industry) and that how some selected factors (sector affiliation, headquarters-plant relation, geographical location and social, economic environment) have affected their emergence, because these factors have so far received little attention. We proved that these factors also matter in the spread of Industry 4.0 and determined the degree of their impact based on empirical data.

6. Our research revealed that the origin of the business owners, which is also a relevant influencing factor, plays an important role in the spread of Industry 4.0. It is particularly important factor in peripheral regions, where usually foreign enterprises are the major investors.

In the north-eastern half of the country, which can be also considered the eastern periphery of the EU, mainly foreign-owned enterprises are the ones where the application of Industry 4.0 is more advanced. The duality of the industry is reflected not only in space, but also in the occurrence of new technologies.

7. The leading sector of Hungarian industry is the automotive industry, in which significant spatial changes have been started in the past decade. Quality indicators expressing upgrading show correlation with the spatiality of car factories and Tier 1 suppliers carrying out more complex activities, however, more significant functional upgrading is only realized in the capital city with an increasingly research-development focused profile. In the past decade, geographical concentration and expansion simultaneously characterized the sector. The results suggest, on the one hand, only moderate upgrading despite the gradual adaptation of Industry 4.0 and on the other hand, an eastward shift in the motor vehicle industry due to the realization of different ongoing investments. The largest growth can be expected in Hajdú-Bihar county located in the Great Plain.

8. The sectoral structure of Hungarian industry determines the spatial pattern of digitalization to a certain degree. Using data from 2014 to 2019 for sectors classified according to technology intensity and indicators measuring digitalisation trends, we have conducted a correlation and cluster analysis of Hungarian districts (formerly LAU1 level). One of the most important findings in the early stages of the 4IR is that there is a close correlation between the sectoral structure of the Hungarian manufacturing industry with differing technological intensities and the degree of digitalisation. The other main conclusion is the increase in regional inequalities, which indicates unfavourable processes within the Hungarian manufacturing industry. This may lead to the creation of new development paths in the initial phase of the 4IR.

9. The spread of Industry 4.0 technologies also affects industrial employment. Based on the available data on new technologies, we found that Industry 4.0 technologies are even less widespread today. Their impact on the Hungarian industrial employment is not spectacular either. This was also proved by the analysis of the industrial employment data between 2011-2021 from different aspects. In spite of the spread of new technologies, the number of the industrial employees has increased in Hungary during the last decade. The growth was the highest in the machinery industry. The number and share of industrial employees are usually high in the northern part of the Transdanubia and in the north-eastern part of the country. In the longer term, however, significant changes can be expected in the industrial employment, which will not leave the geography of the industry untouched.

10. Since the first industrial revolution, the workforce has had to constantly adapt to new technological challenges. Each industrial revolution required new skills and competencies. Based on extensive bibliometric analysis and empirical research, we have revealed the skills and competencies that will be important in the labour market and employment in the age of Industry 4.0. Based on the synthesis of the various research results, we determined four main groups of skills and competencies (personal, social/interpersonal, technical, methodological). Among them, technical skills and methodological skills are considered the most important, which was also confirmed by the experience of company surveys.

11. The revolutionary changes taking place in industry also affect higher education and vocational training. The cooperation of the three spheres (government-industry-university) has become more and more important in recent years. Based on various databases and qualitative

research, we examined what changes occurred in the spheres of the triple helix and in their cooperation and how they affected the spatial structure of the Hungarian industry. German companies are leading in the application of I4.0 technologies and in the introduction of dual training in Hungary, as well as in encouraging cooperation between spheres. We evaluated from the point of view of a multi-site German company (Continental) and a university (University of Miskolc), using the example of mechatronics engineering education to present the characteristics of cooperation in connection with the new technologies. The research drew attention to the fact that the change in the training structure and the closer cooperation between universities and industrial companies, which was also motivated by the technological revolution, can greatly influence the economic development of a settlement and also affect the territorial structure of the Hungarian industry in the era of the fourth industrial revolution.

12. The outbreak of the Covid-19 pandemic also affected industrial enterprises producing various products for the health sector. The research demonstrated how the Healthcare Industry Support Program announced in 2020 contributed to the digitalization of domestic healthcare enterprises, and where and what Industry 4.0 technologies appeared, and how their regional distribution was related to the spatial structure of the Hungarian industry. Healthcare enterprises were highly concentrated in space and were more frequent primarily in the northern, more industrialized region of the country.

Taken as a whole, the various partial results indicate that since 2011, but especially in the last years, new trends have been observed in the dual spatial structure of the Hungarian industry. A slow shift took place towards the eastern – north-eastern part of the country and along the Danube, in the central part of the country. It has also been proven that ‘path dependence’ also prevails in the sectoral structure of the industry, and to a certain degree determines the spread of new technologies. As a consequence, it seems that Industry 4.0 has not yet considerably contributed to the ‘breaking’ of previous territorial/corporate development paths and to the creation of a new industrial structure and a new spatial pattern in the Hungarian industry.

There are three publications which have already been accepted and their publishing is expected next year. One of these is a book chapter. This micro-level research evaluated the impact of industrial revolutions on local industry, land use and employment on the example of a settlement (Esztergom), which is now one of the centres of car industry. In the framework of an article, we explored the most important characteristics of the enterprises that received support in different periods of the Healthcare Industry Support Program. We also analysed the adoption of Industry 4.0 technologies in these companies and their geography in connection with industrial space. In the third study, we examined the spatial patterns of manufacturing industries with different technological intensities and Industry 4.0 technologies at the county level in the initial phase of the fourth industrial revolution.

Two articles on the Hungarian TCFL sector in global context are under reviewing. Apart from these, the preparations of further publications related to the topic can be expected in the future. As a result, the number of publications linked to the project will surely increase.

There are further opportunities to continue the research, which is related to the pioneering nature of the topic and to the fact that in the coming years more and more accurate information will be available on the spread of Industry 4.0 technologies, and because the extraordinary impact of the pandemic will be much less in the completion of the fourth industrial revolution.

Newer research enables the acquisition of additional knowledge about the spatial processes of the Hungarian industry owing to Industry 4.0 technologies.

The main results of the research are also indicated by the following data:

1. Total number of presentations: 19. (The PI was the only author 9 of them.)
at international events: 11.

In addition, the PI also organised an international conference on Industry 4.0 (IGU CDES. Budapest, Oct.4-6, 2019), and a special session on the 4IR (XI. Hungarian Geographical Conference. Oradea, Oct.12-16, 2023).

2. Total number of publications published: 24

in domestic journals in Hungarian language: 4

in domestic journals in English: 3

in foreign journals: 6

book chapters: 3

others:8

under publishing:3

under reviewing: 2.

In addition, the PI edited a special issue on Industry 4.0 in the Hungarian Geographical Bulletin (2021.2).

The utilization of research results is possible in several ways. On the one hand, they can contribute to broadening the theoretical and partly methodological knowledge and literature of domestic geography/economic geography. On the other hand, practical professionals (e.g. employees of government offices and municipalities, economic and regional development specialists, company leaders, managers, workers in education, vocational training and employment) who work in various areas of life can also provide usable information, but for the society as a whole can also provide new knowledge in the period of the fourth industrial revolution.