Spatial patterns of the Hungarian Healthcare Industry Support Program in connection with Industry 4.0 technologies during the Covid-19 pandemic

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The outbreak of the Covid-19 pandemic primarily and directly affected health care and its background sector, the health care industry, whose development has become a national economic priority since the 2010s. The epidemic also necessitated quick and effective adaptation and immediate reactions in Hungary. One of these was the introduction of the Healthcare Industry Support Program (HISP) in 2020 with the aim of promoting effective protection against epidemics. The main aim of this study is to reveal the major differences in the characteristics of the enterprises supported in the different periods of the HISP with particular regard to their Industry 4.0 technologies and spatial pattern in connection with the Hungarian industry. Based on different data sources and empirical research (questionnaire survey), the authors found that there are significant differences between the subsidized enterprises in the two main support periods. Although technology-based developments came to the fore in the age of the pandemic, this has not resulted in the widespread spread of Industry 4.0 technologies in the Hungarian health care industry, whose spatial pattern was closely connected to the Hungarian industry.

Introduction

The Covid-19 pandemic that broke out in 2020 created a new situation and resulted in countless unprecedented changes in almost all areas of life, of which the health care sector was the earliest to face critical issues and novel opportunities for their resolution. During this extraordinary period, the prompt reaction of the health care industry was particularly important, as it provided the health care system with essential products and services to mitigate the epidemic and operate health care services. Using the technological achievements of the fourth industrial revolution decidedly plays a vital role in the development of effective adaptation strategies and the realization of appropriate resilience.

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The health care industry is connected to almost all sectors of the economy, and its importance goes beyond the framework of the national economy. Its innovative, research-intensive and technology-intensive activities have important opportunities for international application, and they have multiple favourable features on the global market (Rosow–Adam 2014). The health care industry not only encourages the creation of jobs and workforce training but also strengthens businesses and makes the health care system more efficient for better resource allocation and care organization (Seaman 2004). It promotes the expansion of exports, sustainable economic growth and increased competitiveness (Folland et al. 2017). It also contributes to the strengthening of global supply chains and the wider application of new technologies.

The global pandemic has highlighted that national governments and special political measures have decisive importance in the management of epidemiological emergencies. During the epidemic, very relevant and complex state interventions have also been realized in Hungary. One of the economic protection measures was the introduction of the Healthcare Industry Support Program (HISP), which may directly and indirectly affect firms and the development of the health care industry. In this study, the emphasis is on the examination of this program. Based on different data sources and qualitative research, the main aim of the study is to reveal the major characteristics of the enterprises supported in the different periods of the HISP with particular regard to the adoption of Industry 4.0 technologies and their spatial pattern. In connection with these, the major research questions were the following:

– What are the principal characteristics of the HISP and the enterprises supported in the different periods of the HISP with a special focus on the territorial aspect?
– Have Industry 4.0 technologies been implemented in the development of the health care industry due to the challenges of the epidemic? If so, was the top-down or bottom-up strategy more prevalent in their spread?

The underlying hypothesis is that the challenges triggered by the Covid-19 pandemic in the health care industry have accelerated the spread of Industry 4.0 technologies, and this development is closely related to the spatial structure of the Hungarian industry in particular.

This study consists of three main sections in addition to the introduction and conclusion. First, based on the literature, we interpret the concept of the health care industry. Then, we evaluate the relationship between the epidemic and the health care industry in the age of Industry 4.0, as well as the presence of the latter in the Hungarian health care development policy. In the second section, the various data sources and research methods are demonstrated. The third section includes the research results and discussion: we analyse the most important characteristics of the HISP and Hungarian enterprises supported, and we also evaluate the outcome of the

questionnaire survey in detail, with a special focus on the application of Industry 4.0 technologies and their spatial pattern. Finally, conclusions are drawn.

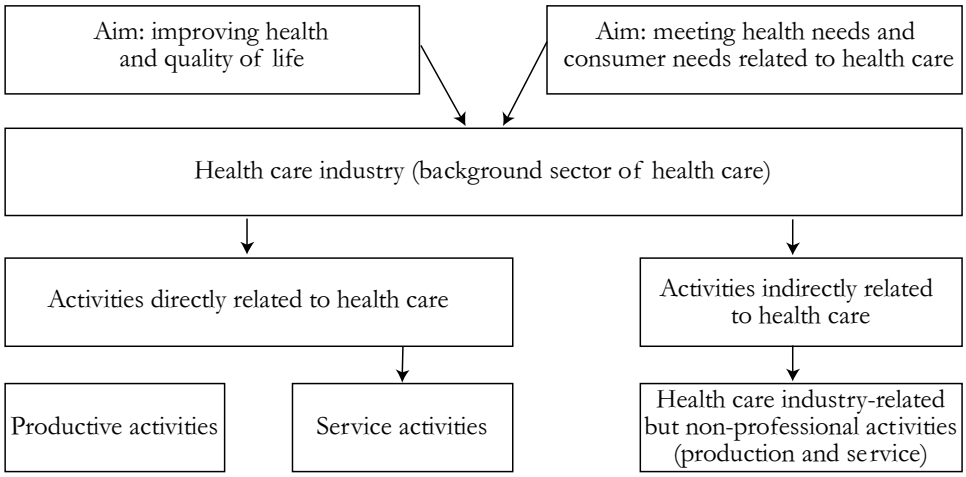
Research background

The concept of the health care industry

The health care industry integrates a variety of activities essentially related to all economic sectors. Due to its complexity, it is present not only in production processes but also in services, as well as in research and development (R&D). For all these reasons, it is difficult to define exactly. A multidisciplinary approach enables the continuous updating of the use of the concept and the application of both broader and narrower interpretations. The latter primarily integrates activities that are directly related to health care to improve health and quality of life, while the former also contains indirectly connected, nonprofessional activities (Figure 1).

Figure 1

Conceptual framework of the health care industry



Source: Edited by the authors, 2022.

The health care industry is the background branch of the health care sector, the main purpose of which is to serve health care needs and consumer needs related to health (ÁEEK 2021, Csizmadia 2010, Kansky 2016). A further similarity is that the activities of the health care industry are primarily related to the curative, nursing, preventive and rehabilitation tasks of health care (Kincses 2010), which can tend to product manufacturing, organization, education, R&D, communication, insurance, etc., tasks (Szakálné Kanó 2018, Ledesma et al. 2014, Seaman 2004).

In the United Nations International Standard Industrial Classification of All Economic Activities (ISIC) system, health care industry activities appear mainly as

industrial activities, which primarily include production, product manufacturing and the preparation of health care industry goods. At the same time, in the Global Industry Classification Standard categorization system, health care industry activities are related to the production of medical equipment, instruments and health services, as well as the pharmaceutical industry, biotechnology and related life sciences. While the former group primarily includes production activities, the latter involves service activities (Hernandez et al. 2009).

Based on the Hungarian literature, the most generally accepted categorization of health care industry activities is attributed to Kincses (2010), which is as follows:

1. Services of the health care system, e.g., from prevention through treatment to rehabilitation.
2. Professional services and professional suppliers that support the operation of the health care system, e.g., pharmaceutical production, production of medical instruments, health informatics, financing and insurance mechanisms.
3. Nonprofessional services and nonprofessional suppliers supporting the operation of the health care system, e.g., medical clothing, energy supply, waste management, food supply.
4. Lifestyle industry: based on health promotion, e.g., the beauty industry, health tourism, the hygiene industry, lifestyle consulting, recreation services, production of nutritional supplements, leisure sports.

In this definition, health care is indeed part of the health care industry, and more emphasis is placed on health care industry activities with a service function. Based on Hungarian activity classification (TEÁOR'03), Szakálné Kanó (2018) determined which sectors belong to the health care industry. Among them are production and service activities, which essentially means a broader interpretation of the health care industry. From the perspective of this study's topic, we also interpret the concept of the health care industry broadly. Due to the HISP, a specific definition of the health care industry was created to integrate all those activities that are both directly and indirectly related to the health care industry.

The health care industry and the Covid-19 pandemic in the age of Industry 4.0

Research in the health care industry does not have a long history. Based on the [3] database, publications with the term "healthcare industry" in their titles have appeared for a few decades. Their increase started in 2010, but the Covid-19 pandemic has pushed those studies addressing the issues of the health care industry into the background. The vast majority of publications were published in Anglo-Saxon countries, and their topics were very diverse [3]. Based on the relationship between the Covid-19 pandemic and the health care industry, three main research directions

were distinguished (examining the role of health care needs, state and market players and research and development and innovation [R+D+I]) in foreign literature.

In Hungary, health care industry research also received little attention before the epidemic, and the number of publications has only increased in recent years. These studies partly dealt with theoretical and conceptual issues (e.g., Kiss–Uzzoli 2021, Szakálné Kanó 2018). Some were focused on the analysis of the connection between the Hungarian health care industry and regional development (Elekes 2018, Nagy 2018, Szakálné Kanó 2018), while others were based on discovering the role of domestic decision-making in its development (Lengyel 2018).

The global pandemic, which depends on various factors, has significantly affected the health care industry, the investigation of which requires a complex approach (Antulov–Fantulin et al. 2021, Wernli et al. 2021). During each epidemic wave, the health care industry faced different challenges and new phenomena, which affected different countries of the world to different degrees (Ahmad–Chakole 2021). The effects of the pandemic on the health care industry appeared in the short, medium and long term (Cutler 2021).

In the short term, the outbreak of the pandemic produced a transformation of needs related to health care industry activities, a „phase shift" of demand and supply, stock shortages and state interventions, which affected all countries of the world at the same time. On the one hand, demands for products and services related to the pandemic have increased on the parts of the health sector and population (Rinswer 2021). On the other hand, there were state interventions (e.g., border closures and restrictions) directly associated with the reduction of production capacities, global supply disruptions and total or partial product shortages (Baldwin–Weder di Mauro 2020, Koós et al. 2020, Nicola et al. 2020). The intensification of the problems and challenges occurred mainly in those countries (e.g., Italy, United States, China) where the pandemic was associated with an exceptionally high number of cases from the very beginning. Furthermore, it also adversely affected those (e.g., in Central and Eastern Europe) that were self-sufficient to a lesser extent in the production of the health care industry products necessary for protection and in the provision of health care services. Many countries, mainly less developed countries, however, were only able to implement the expansion of production capacities to produce the products necessary for epidemic control, which they did in parallel with stopping or reducing the production of other industrial products (Bong et al. 2020).

It became clear in the medium term that the prolongation of the pandemic and the formation of new waves could be expected. At the same time, the countries of the world realized that in the long term, it had become necessary to expand the capacities of certain health care industry activities, to alleviate import dependence, to support local small and medium-sized enterprises connected to the health care industry and to develop the conditions for R&D and digitalization (Rinswer 2021). The latter process and the realization of technology-based developments in the health

care industry were closely related to the spread of Industry 4.0 technologies (Popov et al. 2022, von Eiff–von Eiff 2020, Harbeck 2019). This was also accelerated by the Covid-19 pandemic (La Rue et al. 2022, Quadri et al. 2020).

The concept of Industry 4.0 appeared for the first time in Germany in 2011, and it essentially refers to nine new technologies (big data, augmented reality, autonomous robots, simulation, cloud system, horizontal/vertical integration, the Internet of Things, cybersecurity and additive manufacturing) (Rüßmann et al. 2015). They are the main driving forces of the fourth industrial revolution, which is now also referred to as Industry 4.0 and which has resulted in revolutionary changes in industrial production and the economy and society as a whole (Schwab 2016). These new technologies resulted in a paradigm shift in the health care sector and promoted recovery from the crisis induced by the pandemic because they created new conditions and opportunities for the health care sector, for example, in epidemic prevention (mobile applications) and how to organize medical treatment (online appointment booking) (Tyminski 2022). In fact, the publications in the [3] database with the words "Industry 4.0" and "healthcare industry" in their titles (34 in 2023) also report on these topics, e.g., how different new technologies are used in health care or what their advantages are (Aceto et al. 2020, Kotzias et al. 2022, Paul et al. 2021). The systematic literature analysis and the literature evaluation of some publications also revealed that the investigation of the connections between the health care industry and Industry 4.0 has not received much attention in the research thus far (Sibanda et al. 2022, Mwanza et al. 2023). This study is also novel in that it examines the effects of state intervention through the HISP in connection with Industry 4.0.

It is also a fact that there were no uniform regulations either in epidemic control or in interventions related to the health care industry. Even within the European Union, the member states were not able to harmonize their pandemic measures (Amdaoud et al. 2021, EC 2021). In essence, European countries took the position that the development of regulations and interventions related to the epidemic falls within the scope of national sovereignty. As a consequence, each country had different responses to the health care industry-related challenges of the pandemic depending on the country's socioeconomic development, political system, position in the world economy, and even its institutional background (Kuhlmann et al. 2021).

Among the East Central European states, the vulnerability resulting from the fragility of supply chains encouraged Hungary to begin large-scale health care industry developments in the summer of 2020 to be self-sufficient in indispensable health equipment and services (Bán et al. 2018, Kiss–Uzzoli 2021, Uzzoli et al. 2020). Although the development of the health care industry has already received special attention in Hungary since 2010, which was confirmed by the introduction of several strategic plans and programs (e.g., New Széchenyi Plan 2011, Semmelweis Plan 2011, National Development and Territorial Development Concept 2013, National

Intelligent Specialization Strategy 2014, Irinyi Plan 2016, Digital Health Industry Development Strategy 2017), a marked change was only brought about by the Covid-19 epidemic in Hungarian health policy. The prominence of the health care industry in strategic developments was also related to the fact that significant health inequalities prevail in Hungary (Bálint 2012, Pál et al. 2021, Pirisi–Trócsányi 2011, Egri 2017, Kiss 2016, Uzzoli 2016). Mitigating them was in turn articulated as a strategic goal by Hungarian health policy-makers. These health inequalities have also been observed in Covid-19 mortality, resulting in excess mortality (Bucci et al. 2023, Igari 2023).

The unexpected predicaments entailed a rethinking of the previous developmental directions, resulting in the introduction of a new support program in Hungary. The HISP announced in the summer of 2020 provided applicants with a nonrefundable subsidy. Tendering and support largely took place in three stages: the first occurred in the fall of 2020, the second in the spring of 2021, and the third in late 2021-early 2022. The most important requirements for the applicants were the following: the smallest eligible project size was set at HUF 400 million. In the case of investments, at least half of the eligible costs had to be spent on the purchase of machines and equipment. At the same time, the proportion of infrastructural and real estate investment could be no more than 50% of the eligible costs. The other important criteria were that a maximum of 80% of the planned investments would be covered by the HISP in the case of the production of products related to the coronavirus epidemic. There was no accessible information about how many companies actually applied within the framework of the HISP and what the actual criteria for selecting the winning applications were. The supported companies had six months to implement the investment and to respond more effectively to the challenges of the epidemic [2].

Data and methods

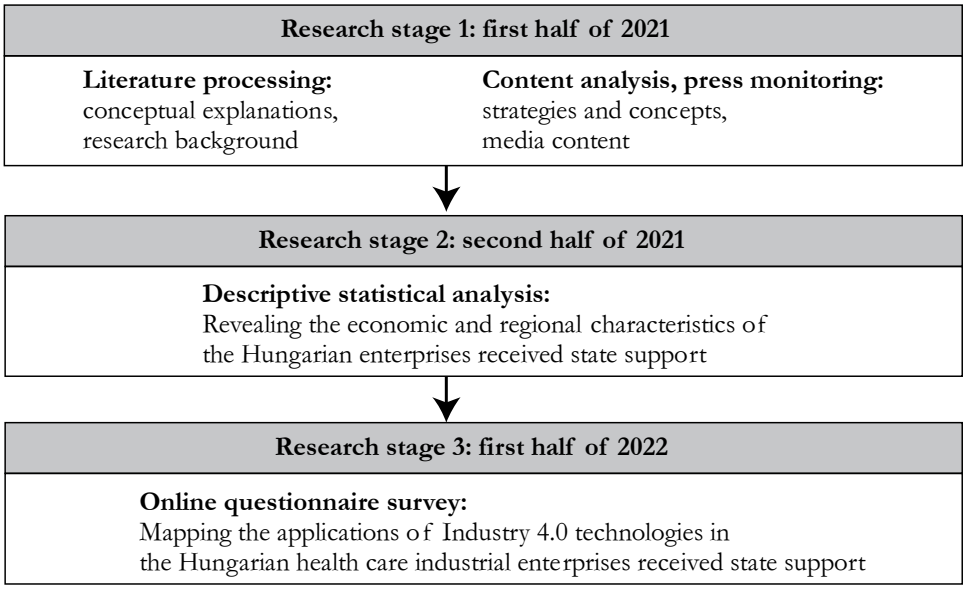
During the research, which basically consisted of three main stages, the emphasis was placed on the territorial approach to the connections between the pandemic, health care industry enterprises supported and Industry 4.0. Both the health care industry and Industry 4.0 are multifactorial concepts: thus, the complex interpretation of their geographical characteristics requires the application of several methods. Hence, we combined quantitative and qualitative methods in the research, making it possible to coordinate the results of the statistical data analysis with the findings of the content analysis and those of the questionnaire survey (Tariq–Woodman 2013, Wisdom–Creswell 2013).

The tasks of each research phase were built on each other and facilitated the answering of the research questions and the realization of the goal set up in a complex way, which contributes to a more accurate understanding of the health care industry

and geographical context of the rapid government intervention in an extraordinary situation (Figure 2).

Figure 2

Research stages and tasks



Source: Edited by the authors, 2022.

In the first phase of the research, we processed the literature and collected data and information about the HISP and the supported enterprises. Information about the HISP was collected from government websites and companies' websites (using press monitoring and content analysis methods). The different data and information sources made it possible to check and correct the content of the information because an official list of the winning applicants and the selection criteria were not available and not even the total number of applicants. It can be assumed that this information was kept confidential for various reasons.

A total of 83 health care industry investments received support within the HISP, which 56 companies planned to implement. However, of them, only 41 companies' names could be identified by using different governmental news. Nineteen received support in the first phase in 2020, 18 in the second phase in spring 2021 and only 4 in the third phase in 2021/2022 because the pandemic situation improved considerably. The time of the actual assessment of the subsidies also justified the merging of the last two periods, when altogether 22 companies were subsidized. The firms of the two main support periods (2020, 2021) were compared from different perspectives in the second stage of the research. Detailed information (e.g., year of foundation, size, activity, location) about these firms was available in [1] firm database,

providing complex and relevant information about the financial and legal situation of firms, their networks and other parameters.

In the third phase of the research, an online questionnaire survey was conducted among the 41 firms in the summer of 2022. The sample of the questionnaire was generated by Google Online Form Creator. The survey questions were related to the following main topics to gain such information, which is mostly not available from other sources:

- General data and information about the company,
- Reasons and results of the firms' participation in the HISP,
- Emergence of Industry 4.0 technologies in subsidized health care industry development.

The questionnaires were sent to all subsidized firms, and to increase the response rate, the direct inquiries (by email and phone calls) were repeated several times. In spite of this, only 10 companies (24%) answered the questions. Although the sample size is too small, it can be considered appropriate because the willingness of companies to respond is generally very low in other countries as well (Tortora et al. 2021, Yüksel 2020). The companies that replied do not form a representative sample. It was completely random which companies answered the questionnaire. In addition to the nonrepresentative questionnaire survey, the research has other limitations. As mentioned earlier, due to the lack of an official list of the winning HISP applicants, it was difficult to obtain accurate information about the companies. Moreover, there is little data available on the entire domestic health care industry: thus, we have incomplete knowledge about the sector itself. This is in close connection with the complex and different interpretations of the health care industry. Despite the limitations, this study provides a methodologically complex perspective on examining the connection between the health care industry and Industry 4.0 technologies from the point of view of the HISP.

Results and discussion

Some characteristics of the HISP

Comparing the characteristics of the subsidized companies in the two periods shows a decided difference. There are also considerable differences in the development goals of Hungary. In the first year, the production of medical equipment and disinfectants was the most important task. Promoting the long-term growth and boosting the export capacity of the health care industry became priorities in the second year of the epidemic.

In the two support periods, 41 enterprises received a total of HUF 47.8 billion in support. In the first period, a total of HUF 28 billion was given to enterprises supported: in the second period less than that, HUF 19.8 billion. Hence, an average of HUF 1.4–1.1 billion was allocated to a company in each period (Table 1).

Table 1

Healthcare Industry Support Program in Hungary by support periods, 2020 and 2021

Denomination	First support period, 2020	Second support period, 2021
Total value of the HISP support	HUF 28 billion	HUF 19.8 billion
Average amount of support per enterprise	HUF 1.387 billion	HUF 1.126 billion
Share of planned projects with total value over HUF 1 billion	47% over HUF 1 billion	55% over HUF 1 billion
Total value of smallest and largest project planned	smallest: HUF 340 million, largest: HUF 12 billion	smallest: HUF 400 million largest: HUF 70 billion
Proportion of health care industry support received (average)	80% of developments financed by the HISP	26% of developments financed by the HISP
Own part in the planned project (average)	20% of developments self-financed	74% of developments self-financed
Nature of supported investment	capacity expansion, establishment of new production line, infrastructure development, product development, technical development	capacity expansion, creation of new production line, establishment of new plant, production of equipment, technological development
Nature of supported health care industry development	directly related to epidemic protection: production of rubber gloves, masks, disinfectants, medicines, hospital equipment, ventilators, special packaging, hazardous waste storage	*directly related to epidemic prevention:* production of rubber gloves, production of equipment that can be used at increased risk of infection, production of sterile dressings, production of parts for ventilators, production of hygienic paper products, production of vials/syringes/masks/protective equipment/medicine, production of telemedicine equipment *indirectly related to epidemic prevention*: unique production line for the production of special microscopes, development of laser equipment, development and production of a diagnostic system supported by artificial intelligence, 3D printing for hospital equipment

Source: Based on data [1] and [2] edited by the authors, 2022.

The total value of 21 (51%) of the planned projects exceeded HUF 1 billion. The largest investment was implemented in Környe, with a cost of HUF 70 billion, while the total cost of the smallest project was HUF 340 million, and it was implemented in Tiszapüspöki. The financial support amounted to a different proportion of the cost of the calculated investments. For 80% of the enterprises, the level of support exceeded 70% of the total cost of the project, i.e., the proportion of support was very high for most of the enterprises. Especially in the first period, several companies received full (100%) support. Most likely, because at the beginning of the epidemic,

it was impossible to know how fast it would spread and how severe it would be, companies had to be encouraged to take immediate action for which full support was a great help. In the first period, the smallest share of support was 49%, while in the second period, it was 6%. In the majority of enterprises, the value of their own share was below 30%.

In the beginning, the support of production activities was more substantial in an effort to meet the increased demand for health care industry products. Meanwhile, the other goal was to reduce import dependence and increase self-sufficiency. In the second period, the proportion of subsidized enterprises (44%) performing diverse services (e.g., commerce, R&D) grew significantly. During this period, it became apparent that the investments were aimed not only at self-sufficiency but also at expanding export opportunities and strengthening international competitiveness. Clearly, from 2021, the support of investments seen as essential in the long term in the various areas of Hungarian health care will be given priority in health care industry developments.

Enterprises supported within the HISP

A small part of the companies supported by the HISP were not connected to the health care industry before the epidemic, because they did not perform any health care industry activities. These companies just entered the health care industry sector via the support program, and in fact, it is also possible that the subsidized health care industry activity ceased after the end of the epidemic.

In the two support periods, there are also significant differences in the characteristics of the supported companies, even though approximately the same number of companies were supported by the HISP (Table 2).

The companies supported in 2020 have a longer history, as more than half of them were established before the turn of the millennium. This suggests that the majority of the companies have long-term operation and economic stability. The size of the supported enterprises shows a rather wide range. Among them are microenterprises with a few employees as well as large-sized companies with several hundred employees. However, the largest proportion (83%) of subsidized businesses are small and medium-sized enterprises. The proportion of companies with more than 250 employees was 17%. The number of employees varied between one (mDurance Labor Kft.) and 1720 people (Becton Dickinson Hungary Kft.). Support for larger enterprises was more significant in the first support period, whereas in the second period, more small and medium-sized enterprises received support. This difference accounts for the lower sales revenue of the companies, which could also be explained by the loss of revenue due to the pandemic.

Table 2

Enterprises supported by the HISP in Hungary, 2020 and 2021

Denomination	First support period, 2020	Second support period, 2021
Number of enterprises supported	19	22
Year of foundation	53% founded before 2000, 16% after 2010.	41% founded before 2000, 32% after 2010.
Size category	5 enterprises with less than 50 employees 9 enterprises with 50–249 employees 5 enterprises with more than 250 employees	13 enterprises with less than 50 employees 7 enterprises with 50–249 employees 2 enterprises with more than 250 employees
Average sales	HUF 4.056 billion in 2019.	HUF 0.176 billion in 2020.
Location of headquarters	58% of supported enterprises based in Budapest agglomeration.	55% of supported enterprises based in Budapest agglomeration.
Number of plants	32% of supported enterprises with more than one plant.	64% of supported enterprises with more than one plant.
Main activity	The main activity of 17% of supported enterprises related to the health care industry (mainly producing pharmaceuticals and medical instruments).	The main activity of 23% of supported enterprises related to the health care industry (mainly producing pharmaceuticals and medical instruments).

Source: Based on data [1] and [2] edited by the authors, 2022.

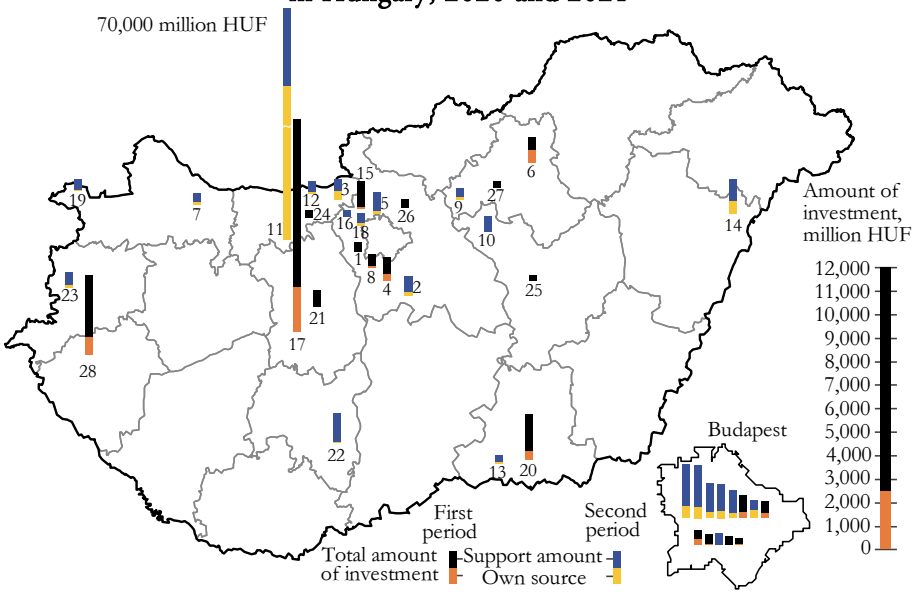
The majority of the enterprises (63%) are engaged in production activities and represent various sectors of the manufacturing industry (pharmaceutical industry, machinery industry, paper industry, plastics industry, metal industry, etc.). The relationship between companies' main activity and subsidized health care industry investment can be classified into two main types depending on whether the company's health care industry activity is related to its main activity. In the former case, the objectives were, e.g., the expansion of the product range and an increase in production capacity, while in the latter case, the objectives were to supplement the nonhealthcare industrial main activity or, alternatively, to transform the production of the firm wholly for the needs of health care (e.g., a paper industry company started producing masks).

There was no marked difference in the geographical distribution of the support. In both periods, most firms in the Budapest agglomeration received support. In addition, the businesses located in some remote settlements (e.g., Eger, Nyíracsád, Sárszentmihály, Szeged, Zalaegerszeg) were also supported (Figure 3).

The main reason for the strong spatial concentration of subsidized enterprises is probably that the significant population concentration also represents an important consumer market, where the demand for health care products was much higher. Since delivery is time-consuming and expensive and, moreover, difficult to solve during an epidemic, it was primarily advisable to support businesses that were relatively close to the market.

Figure 3

Enterprises by the amount of HISP support and their own resources in Hungary, 2020 and 2021

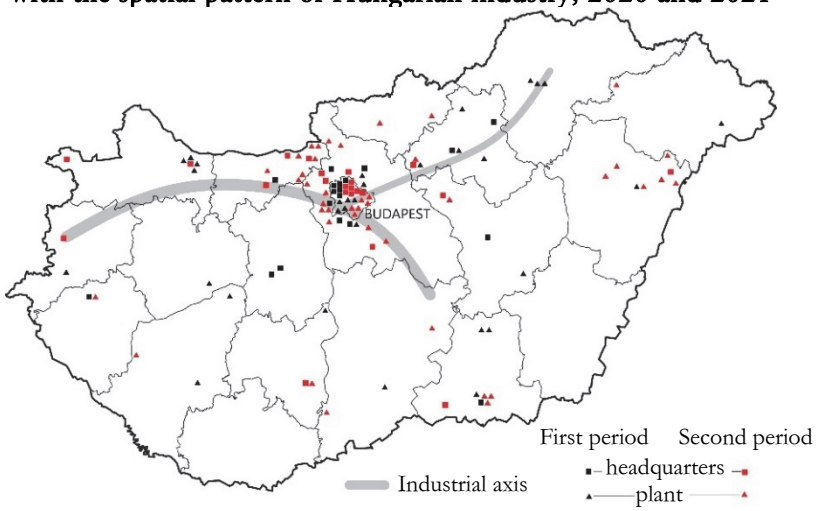


Notes: 1 – Budaörs, 2 – Dabas, 3 – Dorog, 4 – Dunaharaszti, 5 – Dunakeszi, 6 – Eger, 7 – Győr, 8 – Halásztelek, 9 – Hatvan, 10 – Jászberény, 11 – Környe, 12 – Lábatlan, 13 – Mórahalom, 14 – Nyíracsád, 15 – Pilisborosjenő, 16 – Pilisvörösvár, 17 – Sárszentmihály, 18 – Solymár, 19 – Sopron, 20 – Szeged, 21 – Székesfehérvár, 22 – Szekszárd, 23 – Szombathely, 24 – Tatabánya, 25 – Tiszapüspöki, 26 – Veresegyház, 27 – Visonta, 28 – Zalaegerszeg.
HUF 40,000 = approximately EUR 100.

Source: Based on data [1] and [2] edited by the authors, 2022.

Figure 4

Enterprises supported by their headquarters and plants in connection with the spatial pattern of Hungarian industry, 2020 and 2021



Source: Based on data [1] and [2] edited by the authors, 2022.

The 41 companies had a total of 75 plants. Fifty-seven percent of them were connected to companies supported in the second stage. Since six firms did not have a plant, on average 2.1 plants went to enterprises having plants. Thirty-nine percent of the enterprises had only one plant, whereas others had two or more (e.g., Metris3D Kft. had five, Thermotechnika Crown Cool Kft. had seven plants). Enterprises with more plants were mainly involved in nonproductive activities (e.g., trade, repair, service activities), which require close proximity to consumers. The other reason for the establishment of new plants is that if there is no possibility to expand the area or carry out certain production activities at the company's headquarters in a town, it might pollute or disturb the environment. Therefore, enterprises tend to set up plants in other settlements of the country or possibly abroad, as in the case of a single cosmetics company with a branch in Paris. Another example is Podiart Kft. which implemented an investment (production of medical devices with 3D printing) at its plant located in the countryside acquiring a property available only there thus making the investment feasible. Fifty-six percent of the enterprises had their headquarters in the capital city region, while plants were typically scattered in different parts of the country. The support probably reached them through the company's headquarters and largely contributed to their survival and development during the pandemic (Figure 4).

The geography of the supported firms (headquarters and plants) followed the spatial pattern of the Hungarian industry being primarily concentrated in the northern part of the country, where industrial activity is more significant and where recent and cutting-edge information and communication technologies are more commonly used (Kiss–Nedelka 2020). Since there are hardly any newly founded companies among the subsidized enterprises, it can be concluded that the supported health care industry companies did not participate in shaping the spatial structure of the Hungarian industry. Based on these, it can be assumed that they did not have a significant impact on the spatial pattern of the health care industry either, since the investments were connected to already operating businesses. The spatial distribution of the health care industry is also difficult to define precisely, depending on the interpretation of the term. If we only consider the production activities of the health care industry, there can be significant differences among manufacturing branches, although the location of the health care industry is usually spatially concentrated. For example, the pharmaceutical industry has a well-defined spatial pattern: since it is capitalintensive and employs many skilled workers, its location is highly concentrated (Lengyel 2018, Lengyel et al. 2016, Nagy et al. 2023, Nagy 2016, 2018, Szakálné Kanó 2018). At the same time, the companies operating in the food industry, which sell some kind of health product, are mostly scattered throughout the country. Due to these factors, the regional distribution of the examined health care industry enterprises contributes to the conservation of the dual industrial spatial structure of the Hungarian industry even during the fourth industrial revolution.

Industry 4.0 technologies in the supported enterprises from a survey

Ten companies replied to the questionnaires, 60% of which received support in the second support period. Most of the companies were established after the turn of the millennium and are small enterprises. Their main activity is primarily productive activity (production of medical devices, production of plastic packaging devices), which is mostly carried out in the capital city agglomeration. Half of the responding companies were originally engaged in activities directly related to the health care industry (e.g., medical device manufacturing), while the other half were able to start health care industry activity thanks to the HISP (e.g., production of face masks) (Table 3).

Table 3

Major characteristics of the supported enterprises from the survey, 2022

Denomination[a)]	Year of foundation	Main activity of the firm	Number of employees	Location of	
				headquarters	plant
First support period					
R1	1996	Medical device manufacturing	272	Eger	Budapest
R2	2007	Wholesale of wood, building materials and sanitary ware	151	Sárszentmihály	Kál
R3	1993	Wholesale of chemical goods	82	Halásztelek	Miskolc
R4	2015	Medical device manufacturing	5	Budaörs	Siófok Győr Budapest
Second support period					
R5	2011	Medical device manufacturing	19	Budapest	Újhartyán Szeged
R6	2001	Agent wholesale of other products	20	Szombathely	Budaörs Budapest Csákány
R7	1991	Production of plastic packaging	19	Dorog	Leányvár
R8	1991	Medical device manufacturing	19	Budapest	Visegrád
R9	2015	Manufacture of other plastic products	77	Szekszárd	-
R10	2016	Production of plastic packaging	84	Hatvan	-

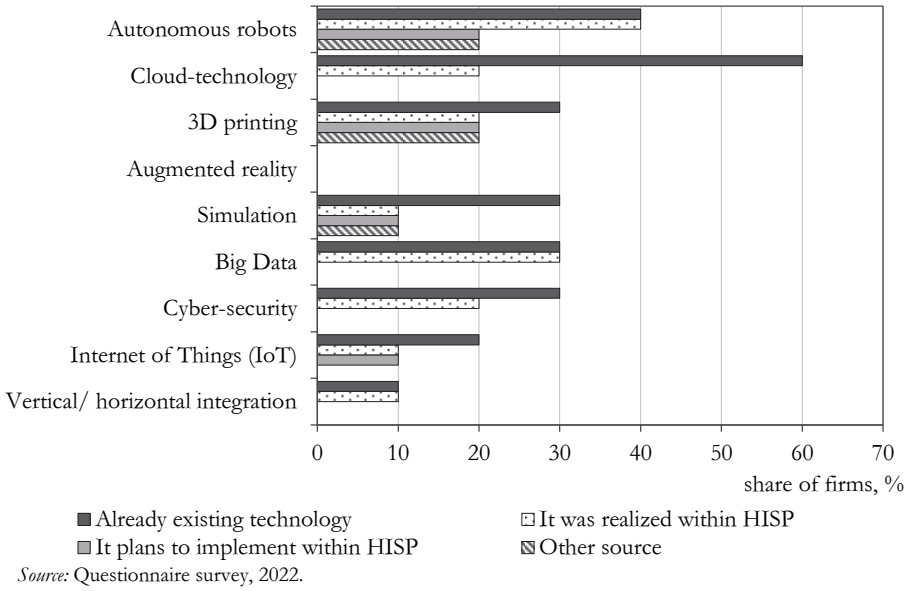
a) R means the enterprises took part in the survey in 2022.
Source: Based on data [1] and [2] edited by the authors, 2022.

According to the results of the survey, the concept of Industry 4.0 and its new technologies have recently become known to enterprises. More than two-thirds of companies have two or more new technologies, which is more favourable than the national average, because their occurrence rate is usually a few percent among businesses (Kiss–Nedelka 2020). This can be explained by the fact that the health care industry is generally a very technology-intensive branch of the economy and that

health care companies usually have significant capital, which enables the acquisition of new technologies. Although there are companies that already introduced Industry 4.0 technology before the outbreak of the epidemic (e.g., company R4 bought a 3D printer in 2017 for the production of Co, Cr and Ti products, company R6 introduced cloud technology in 2016 so that its employees in different parts of the country could work remotely), the majority introduced Industry 4.0 technologies between 2020 and 2022 within the HISP. This also proves that the HISP promoted and facilitated their technological development and had a favourable effect on the spread of new technologies. In some cases, however, EU sources also contributed to the purchase of robots (R1) or 3D printers (R8). Among Industry 4.0 technologies, cloud-based technology is the most widespread, and 60% of the supported companies used this technology. 40% of the companies adopted autonomous robots, which is the other most common technology. These new technologies are of critical importance for health care industry companies, primarily because they largely contributed to production optimization, increase efficiency and improve quality. Of the Industry 4.0 technologies, only augmented reality was not used by any of the companies, which is probably related to the specific nature of this technology, as it is mainly used for maintenance and assembly (Figure 5).

Figure 5

Industry 4.0 technologies by survey and their financial sources, 2022



Source: Questionnaire survey, 2022.

Of the 10 enterprises, the largest (R1) had the most Industry 4.0 technologies (an autonomous robot, cloud system, simulation, cyber security, the Internet of Things, and big data). At the same time, smaller companies (R5, R6, and R7) had less (one-

three) Industry 4.0 technology (a cloud system, robot, and/or 3D printer). Company size is therefore also an important influencing factor in the spread of Industry 4.0 technologies in the case of Hungarian-owned companies (Nagy et al. 2020). It can also be observed that, in general, the application of Industry 4.0 technologies is more advanced in the enterprises located in the capital city and other larger cities. Only one company (R10) did not have any new technologies, which all the companies (except for R6) bought from the HISP. Additionally, within the framework of the HISP, R1, R4, R7 and R9 firms planned to introduce other Industry 4.0 technology (e.g., an autonomous robot, simulation, the Internet of Things, a 3D printer). According to the survey, maintaining competitiveness (R1), reducing costs (R3), manufacturing special products (R9) and implementing remote working (R6) are also important goals of using new technologies.

The findings of the survey also pointed to factors that most often hinder the spread of new technologies. As other research has revealed, one of the main reasons is the lack of labour force and training (Adebanjo et al. 2021, Bravi–Murmura 2021, Hamzeh et al. 2018). The poor level of information technology (IT) competence in the workforce is a particularly unfavourable contributing factor. Another common constraint on the application of Industry 4.0 in the case of 40% of the companies is the highly limited financial resources. The majority of companies (80%) are indeed „open" to innovation, and it rarely occurs that new technology is not implemented due to a lack of interest or motivation. The answers to our surveys revealed that there are factors (e.g., position within the organization, geographical location) that have a very small (10–20%) impact on the adoption of new technologies. However, the influence of sector affiliation and the quality of the products were considered substantially more significant (30–40%). The results of other research also indicate that new technologies spread to varying degrees in different sectors depending on the specifics of the sector (Nagy et al. 2020, Horváth–Szabó 2019). In general, the spatial diffusion of Industry 4.0 is the most advanced in the machinery industry (automotive industry and electronics), while it is less advanced in the light industry or the food industry (Losonci et al. 2019).

The HISP actually facilitated the implementation of the application of Industry 4.0, which also had a positive effect on the overall digitalization of enterprises. Nonetheless, the application of new technologies was not accompanied by a decrease in the number of employees at the examined enterprises because their sustained operation required the hiring of a more qualified workforce.

Based on the answers, the vast majority of companies rated the level of their digitalization as medium on a 5-point Likert-scale in 2022. In the supported health care industry enterprises, the most digitalized corporate activities were related to communication, finance and production, while the least digitalized was HR-management. The greater digitalization of sales suggests that online sales increased during the epidemic. The global pandemic accelerated the application of new

technologies and the process of digitalization (Harbeck 2019, La Rue et al. 2022). The same hypothesis was confirmed by our empirical research, since the application of new technologies has only a short history in most companies. However, the HISP subsidies played a massive role in their appearance during the pandemic years and in the early stages of Industry 4.0, which is, in fact, the fourth industrial revolution.

Based on the survey, the majority of companies implemented the new investment at their headquarters, with only a few in Budapest. As part of the subsidized projects, companies undertook the production of products directly used by the health care sector, e.g., production of medical devices, production of pharmaceutical raw materials, production of medical hygiene devices, production of special bandages, and production of vials. According to the responses, it can be inferred that the implementation of the planned project at the headquarters was primarily due to a better labour supply, a more qualified workforce, greater demands for products and services, and a more developed infrastructure (e.g., at Rex-San Kft.). At the same time, enterprises intended to invest in the plants because they counted on the support of local governments (e.g., in the form of tax incentives and simplified administrative procedures). For example, in the Sárszentmihály investment, the cooperation of the local government accelerated the issuance of building permits. Elsewhere, the municipality helped to secure the necessary workforce (e.g., Igazgyöngy '98 Kft.). With their backing, local governments were able to contribute to the realization of investments in the health care industry and thus to the development of the local economy.

Conclusion

The Covid-19 pandemic shook health care and the health care industry to the core, and the consequences go beyond the short- and medium-term effects of the epidemic. Based on our findings, it is necessary to prepare for the inevitable transformation of the health care industry in the long term. The challenges caused by the epidemic and the crisis created conditions and opportunities for renewal. Several research antecedents have pointed out that the pandemic resulted in a paradigm shift in the health care industry. The essence of this shift is that to offset the adverse effects, innovative solutions different from the previous ones were needed, among which priority was given to research and development, innovation, digitalization and technology-based developments.

In Hungary, the Healthcare Industry Support Program (HISP) announced in the first year of the Covid-19 pandemic helped, in the short term, meet the needs produced by the pandemic from its own resources. It also became obvious that the Hungarian health care sector as a whole received new incentives for renewal and consolidation. In the first period of the support program, the focus of state subsidies was more on production (capacity expansion and product development). From 2021,

however, technical and technological developments increasingly appeared in the activities of the subsidized companies. This is primarily due to the HISP, which actually facilitated the implementation of the „bottom-up" initiative in health care industry companies, e.g., in digitalization. This strategy was more prevalent in the spread of Industry 4.0 technologies than the „top-down" strategy. It is as yet impossible to tell whether all of these will indeed contribute to the international competitiveness of the Hungarian health care industry in the long term, partly because of the short time that has passed, some of the investments are still in progress, and because the epidemic situation, which necessitated the implementation of these investments, has improved. As a result, the importance of these subsidies and investments cannot be considered uniformly. On the one hand, the enterprises that implemented developments relative to production in the first period played an extremely important role in the short term. However, the utilization of the built-up capacities is very uncertain in the long term and may depend on the outbreak of other epidemics or possibly a change in their function. At the same time, those enterprises whose development has been fully or partially realized definitely gained advantages that enable them to react more quickly in the event of a possible new emergency.

To a certain extent, the limitations of the research also determine the possibilities for continuation. Since relatively few companies responded to the questionnaires, one of the main research directions could be the extension of the survey to other companies in the health care industry. It may also be interesting to study the impact of one of the biggest challenges of the past year, the energy crisis, on the health care industry in connection with Industry 4.0.

Taken as a whole, according to the literature, the introduction of the HISP in Hungary was a special governmental intervention to promote effective protection against the Covid-19 pandemic. Revealing its spatial patterns and contribution to the adoption of Industry 4.0 technologies is the main novelty of the study. Although the HISP has contributed to the increase in technology-based development, it did not lead to the widespread distribution of Industry 4.0 technologies. The subsidized health care industry companies did not contribute to the mitigation of the spatial inequalities in the Hungarian industry in the years of the pandemic.

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REFERENCES

ACETO, G.–PERSICO, V. –PESCAPE, A. (2020): Industry 4.0 and health: Internet of things, big data, and cloud computing for healthcare 4.0 *Journal of Industrial Information Integration* 18: 100129. https://doi.org/10.1016/j.jii.2020.100129

ADEBANJO, D.–LAOSIRIHONGTHONH, T.–SAMARANAYAKE, P.–TEH, P. (2021): Key enablers of industry 4.0 development at firm level: Findings from an emerging economy *IEEE Transaction on Engineering Management* 70 (2): 400–416. https://doi.org/10.1109/TEM.2020.3046764

AHMAD, N.–CHAKOLE, S. (2021): Effects of Covid-19 on healthcare industry and public health infrastructure *Bioscience Biotechnology Research Community Special Issue* 14 (6): 164–169.

AMDAOUD, M.–ARCURI, G.–LEVRATTO, N. (2021): Are regions equal in adversity? A spatial analysis of spread and dynamics of Covid-19 in Europe. *European Journal of Health Economy* 22 (4): 629–642. https://doi.org/10.1007/s10198-021-01280-6

BALDWIN, R.–WEDER DI MAURO, B. (eds.) (2020): *Mitigating the Covid economic crisis: Act fast and do whatever it takes* CEPR Press, London.

BÁLINT, L. (2012): Spatial gender differences in life expectancy at birth *Regional Statistics* 2 (1): 108–128. https://doi.org/10.15196/RS02108

BÁN, A.–PÁL, V.–VIDA, GY.–FABULA, SZ.–DUDÁS, G. (2018): The role of internet-based healthcare services in the healthcare process: The example of a Hungarian health portal *International Journal of Healthcare Technology and Management* 17 (2–3): 168–185. https://doi.org/10.1504/IJHTM.2018.10019843

BONG, C. L.–BRASHER, C.–CHIKUMBA, E.–MCDOUGALL, R.–MELLIN-OLSEN, J.–ENRIGHT, A. (2020): The Covid-19 pandemic: Effects on low- and middle-income countries *Anesthesia and Analgesia* 131 (1): 86–92. https://doi.org/10.1213/ANE.0000000000004846

BRAVI, L.–MURMURA, F. (2021): Industry 4.0 enabling technologies as a tool for the development of a competitive strategy in Italian manufacturing companies *Journal of Engineering and Technology Management* 60: 101629. https://doi.org/10.1016/j.jengtecman.2021.101629

BUCCI, A.–IPPOLITI, L.–VALENTINI, P. (2023): Analysing spatiotemporal patterns of Covid-19 confirmed deaths at the NUTS-2 regional level *Regional Statistics* 13 (2): 214–239. https://doi.org/10.15196/RS130202

CUTLER, D. M. (2021): How Covid-19 changes the economics of health care *JAMA Health Forum* 2 (9): e213309. https://doi.org/10.1001/jamahealthforum.2021.3309

EGRI, Z. (2017): Regional health inequalities in the European macroregion from the East Central European perspective *Regional Statistics* 7 (1): 197–224. https://doi.org/10.15196/RS0711

ELEKES, Z. (2018): Az egészségipari exporthoz kapcsolódó termékek feltérképezése a hazai megyékben a terméktér eszközével. In: Lengyel, I. (ed.): *Térségek növekedése és fejlődése: egészségipari és tudásalapú fejlesztési stratégiák* pp. 100–121., JATEPress, Szeged.

FOLLAND, S.–GOODMAN, A. C.–STANO, M. (2017): *The economics of health and health care* Routledge, London.

HAMZEH, R.–ZHONG, R.–XU, W. X. (2018): A survey study on industry 4.0 for New Zealand manufacturing *Procedia Manufacturing* 26: 49–57. https://doi.org/10.1016/j.promfg.2018.07.007

HARBECK, N. (2019): Digitalization in medicine: It is our chance and responsibility now to shape the digital future of breast cancer management *Breast Care (Basel)* 14 (3): 128–129. https://dx.doi.org/10.1159/000501185

HERNANDEZ, P.–TAN-TORRES, T.–EVANS, D. B. (2009): Measuring expenditure on the health workforce: concepts, data sources and methods. In: *Handbook on monitoring and evaluation of human resources for health* pp. 63–78., World Health Organization, Geneva.

HORVÁTH, D.–SZABÓ, R. ZS. (2019): Driving forces and barriers of Industry 4.0: Do multinational and small and medium-sized companies have equal opportunities? *Technological Forecasting & Social Change* 146: 119–132. https://doi.org/10.1016/j.techfore.2019.05.021

IGARI, A. (2023): Spatiotemporal inequalities of excess mortality in Europe during the first two years of the Covid-19 pandemic *Regional Statistics* 13 (3): 510–535. https://doi.org/10.15196/RS130306

KANSKY, J. P. (2016): Managing the business of health information exchange. In: DIXON, B. E. (ed.): *Health information exchange* pp. 77–89., Elsevier, Amsterdam.

KINCSES, GY. (2010): Az egészségipar társadalmi és nemzetgazdasági jelentősége *IME – Interdiszciplináris Magyar Egészségügy* 9 (5): 8–14.

KISS, É. (2016): Területi különbségek a hazai népesség egészségi állapotában, 1989 után *Területi Statisztika* 56 (5): 483–519. https://doi.org/10.15196/TS560501

KISS, É.–NEDELKA, E. (2020): Geographical approach of Industry 4.0 based on information and communication technologies at Hungarian enterprises in connection with industrial space *Hungarian Geographical Bulletin* 69 (2): 99–117. https://doi.org/10.15201/hungeobull.69.2.2

KISS, É.–UZZOLI, A. (2021): Az Egészségipari Támogatási Program kedvezményezett vállalkozásai a világjárvány és a negyedik ipari forradalom idején *IME – Interdiszciplináris Magyar Egészségügy* 20 (2): 42–47. https://doi.org/10.53020/IME-2021-207

KOÓS, B.–KOVÁCS, S. ZS.–PÁGER, B.–UZZOLI, A. (2020): Epilógus: Az új koronavírusjárvány társadalmi-gazdasági hatásai és ezek területi következményei. In: CZIRFUSZ, M. (szerk.): *Területi kihívások és területi politikák Magyarországon, 2010–2020* pp. 123–131., Közgazdaság- és Regionális Tudományi Kutatóközpont Regionális Kutatások Intézete, Budapest.

KOTZIAS, K.–BUKHSH, F. A.–ARACHCHIGE, J. J.–DANEVA, M.–ABHISHTA, A. (2022): Industry 4.0 and healthcare: Context, applications, benefits and challenges *Iet Software* 17 (3): 195–248. https://doi.org/10.1049/sfw2.12074

KUHLMANN, S.–HELLSTRÖM, M.–RAMBERG, U.–REITER, R. (2021): Tracing divergence in crisis governance: Responses to the Covid-19 pandemic in France, Germany and Sweden compared *International Review of Administrative Sciences* 87 (3): 1–10. https://doi.org/10.1177/0020852320979359

LA RUE, E.–SHEEHAN, B. –GARRIGHAN, D. (2022): Covid-19 pandemic instigates rapid healthcare industry technology adoption *Journal of Addictions Nursing* 33 (1): 56–57. https://doi.org/10.1097/jan.0000000000000451

LENGYEL, I. (2018): Az intelligens szakosodási stratégiák alapjai, különös tekintettel az egészségiparra. In: LENGYEL, I. (szerk.): *Térségek növekedése és fejlődése: egészségipari és tudásalapú fejlesztési stratégiák* pp. 11–35., JATEPress, Szeged.

LENGYEL, I. –SZAKÁLNÉ KANÓ, I. –VAS, ZS. –LENGYEL, B. (2016): Az újraiparosodás térbeli kérdőjelei Magyarországon *Közgazdasági Szemle* 63 (6): 615–646.

LOSONCI, D.–TAKÁCS, O.–DEMETER, K. (2019): Az ipar 4.0 hatásainak nyomában – a magyarországi járműipar elemzése *Közgazdasági Szemle* 66 (2): 185–218.

MWANZA, J.–TELUKDARIE, A.–IGUSA, T. (2023): Impact of industry 4.0 on healthcare systems of low- and middle- income countries: a systematic review *Health and Technology* 13 (1): 35–52. https://doi.org/10.1007/s12553-022-00714-2

NAGY, B. (2016): A magyar feldolgozóipar átalakulása 2008 és 2013 között: újraiparosodás vagy térbeli átrendeződés. In: LENGYEL, I.–NAGY, B. (szerk.): *Térségek versenyképessége, intelligens szakosodása és újraiparosodása* pp. 45–61., JATEPress, Szeged.

NAGY, B. (2018): A gyógyszeripar fejlődése az Európai Unió különböző országcsoportjaiban. In: LENGYEL, I. (szerk.): *Térségek növekedése és fejlődése: egészségipari és tudásalapú fejlesztési stratégiák* pp. 36–51., JATEPress, Szeged.

NAGY, CS.–MOLNÁR, E.–KISS, É. (2020): Industry 4.0 in a dualistic manufacturing sector – Qualitative experiences from enterprises and their environment, Eastern Hungary *Hungarian Geographical Bulletin* 69 (2): 157–174. https://doi.org/10.15201/hungeobull.69.2.5

NAGY, SZ.–CHERNIKOV, U. C. –DEGTEREVA, E. (2023): The impact of the pharmaceutical industry on the innovation performance of European countries *Regional Statistics* 13 (1): 94–118. https://doi.org/10.15196/RS130105

NICOLA, M.–ALSAFI, Z.–SOHRABI, C.–KERWAN, A. (2020): The socio-economic implications of the coronavirus pandemic (Covid-19): A review *International Journal of Surgery* 78 (6): 185–193. https://doi.org/10.1016/j.ijsu.2020.04.018

PÁL, V.–LADOS, G.–ILCSIKNÉ, MAKRA ZS.–BOROS, L.–UZZOLI, A. (2021): Concentration and inequality in the geographic distribution of physicians in the European Union, 2006–2018 *Regional Statistics* 11 (3): 1–28. https://doi.org/10.15196/RS110308

PAUL, S.–RIFFAT, M.–YASIR, A.–MAHIM, M. N.–SHARNALI, B. Y.–NAHEEN, I. T.–RAHMAN, A.–KULKARNI, A. (2021): Industry 4.0 applications for medical/healthcare services *Journal of Sensor and Actuator Networks* 10 (3): 43. https://doi.org/10.3390/jsan10030043

PIRISI, G.–TRÓCSÁNYI, A. (2011): Spatial aspects of the ambulance service in Hungary *Regional Statistics* 1 (1): 44–54.

POPOV, V.–KUDRYAVTSEVA, E. V.–KATIYAR, N. K.–SHISHKIN, A.–STEPANOV, S. I.–GOEL, S. (2022): Industry 4.0 and digitalisation in healthcare *Materials* 15 (6): 2140. https://doi.org/10.3390/ma15062140

QUADRI, Y. A.–NAUMAN, A.–BIN ZIKRIA, Y.–VASILAKOS, A. V.–KIM, S. W. (2020): The future of healthcare internet of things: A survey of emerging technologies *IEEE Communications Surveys and Tutorials* 22 (2): 1121–1167. https://doi.org/10.1109/COMST.2020.2973314

SEAMAN, G. (2004): Industrial/management engineering in health care. In: DYRO, J. F. (ed.): *Clinical engineering handbook* pp. 181–188., AcademicPress, Amsterdam.

SIBANDA, K.–NDAYIZIGAMIYE, P.–TWINOMURINZI, H. (2022): Industry 4.0 technologies in maternal healthcare: A systematic review *IFAC Papersonline* 55 (10): 2407–2412. https://doi.org/10.1016/j.ifacol.2022.10.069

SZAKÁLNÉ KANÓ, I. (2018): Az egészségipari tevékenységek térbeli eloszlása Magyarországon. In: LENGYEL, I. (szerk.): *Térségek növekedése és fejlődése: egészségipari és tudásalapú fejlesztési stratégiák* pp. 82–99., JATEPress, Szeged.

TARIQ, S.–WOODMAN, J. (2013): Using mixed methods in health research *Journal of the Royal Society of Medicine Short Reports* 4 (6). https://doi.org/10.1177/2042533313479197

TORTORA, A. M. R.–MARIA, A.–VALENTINA, DI P.–IANNONE, R.–PIANESE, C. (2021): A survey study on Industry 4.0 readiness level of Italian small and medium enterprises *Procedia Computer Science* 180: 744–753. https://doi.org/10.1016/j.procs.2021.01.321

TYMINSKI, G. (2022): Newest healthcare industry trends to combat Covid-19 *Euromedica* 12 (1): 4–5. http://dx.doi.org/10.35630/2199-885X/2022/12/1.ed

UZZOLI, A. (2016): Health inequalities regarding territorial differences in Hungary by discussing life expectancy *Regional Statistics* 6 (1): 139–163. https://doi.org/10.15196/RS06108

UZZOLI, A.–EGRI, Z.–SZILÁGYI, D.–PÁL, V. (2020): Does better availability mean better accessibility? Spatial inequalities in the care of acute myocardial infarction in Hungary *Hungarian Geographical Bulletin* 69 (4): 401–418. https://doi.org/10.15201/hungeobull.69.4.5

YÜKSEL, H. (2020): An empirical evaluation of industry 4.0 applications of companies in Turkey: The case of a developing country *Technology in Society* 63 (101364). https://doi.org/10.1016/j.techsoc.2020.101364

VON EIFF, M.–VON EIFF, W. (2020): Value-based leadership in turbulent times: lessons from the Corona crisis and recommendations for post-pandemic management in the health sector *Leadership, Education, Personality: An Interdisciplinary Journal* 3 (2): 157–169. https://doi.org/10.1365/s42681-022-00029-w

WERNLI, D.–TEDIOSI, F.–BLANCHET, K.–LEE, K.–MOREL, C. M.–PITTET, D.–LEVRAT, N.–YOUNG, O. (2021): A Complexity Lens on the Covid-19 Pandemic *International Journal of Health Policy and Management* 11 (11): 2679–2772. https://doi.org/10.34172/ijhpm.2021.55

INTERNET SOURCES

ÁLLAMI EGÉSZSÉGÜGYI ELLÁTÓ KÖZPONT (ÁEEK) (2021): *Egészségtudományi Fogalomtár.* https://fogalomtar.aeek.hu/index.php/Kezd%C5%91lap (downloaded: September 2022)

ANTULOV-FANTULIN, N.–BEREZOWSKI, J.–BILLER-ANDORNO, N.–BLANCHET, K.–BÖTTCHER, L.–BURTON-JEANGROS, C.–CLAUSIN, M.–ESCHER, G.–FLAHAULT, A.–FUKUDA, K.–HELBING, D.–JAFFÉ, P. D.–JØRGENSEN, P.–KASPIAROVICH, Y.–KRISHNAKUMAR, J.–LAWRENCE, R.–LEE, K.–LÉGER, A.–LEVRAT, N.–MARTISCHANG, R.–MOREL, C.–PITTET, D.–STAUFFER, M.–TEDIOSI, F.–VANACKERE, F.–VASSALLI, J.-D.–WERNLI, D.–WOLFF, G.–YOUNG, O. (2021): Building societal resilience to Covid-19 and future pandemics: a synthesis of the literature and a governance framework for action *Policy Brief* 2021/March. https://www.leru.org/files/GSPI-PolicyBrief_resilience.pdf (donwloaded: November 2022)

CSIZMADIA, N. (2010): Az egészségipar mint kitörési pont *Polgári Szemle* 6 (4): https://polgariszemle.hu/archivum/54-2010-augusztus-6-evfolyam-4-szam/393-az-egeszsegipar-mint-kitoeresi-pont (downloaded: November 2022)

EUROPEAN COMMISSION (EC) (2021): *Overview of the Commission's response* European Commission, Brussels. https://commission.europa.eu/strategy-and-policy/coronavirus-response/overview-commissions-response_en (downloaded: November 2022)

LEDESMA, A.–MCCULLOH, C.–WIECK, H.–YANG, M. (2014): *Health Care Sector Overview.* https://s3.wp.wsu.edu/uploads/sites/606/2015/02/SectorOverview_HC_Spring2014.pdf (downloaded: November 2022)

RINSWER, J. (2021): Coronavirus crisis – Impact of Covid-19 on healthcare industry *NeuroScience.* https://neurosciencecommunity.nature.com/documents/coronavirus-crisis (downloaded: November 2022)

ROSOW, E.–ADAM, J. (2014): Applications of virtual instruments in healthcare *Clinical Engineering.* https://www.researchgate.net/publication/328517319_Applications_of_virtual_instruments_in_healthcare (downloaded: November 2022)

RÜßMANN, M.–LORENZ, M.–GERBERT, P.–WALDNER, M.–JUSTUS, J.–ENGEL, P.–HARNISCH, M. (2015): *Industry 4.0. The future of productivity and growth in manufacturing industries.* The Boston Consulting Group. https://www.bcg.com/publications/2015/engineered_products_project_business_industry_4_future_productivity_growth_manufacturing_industries.aspx (downloaded: June 2021)

SCHWAB, K. (2016): *The fourth industrial revolution* World Economic Forum, Cologne/Geneva. https://www.weforum.org/about/the-fourth-industrial-revolution-by-klaus-schwab (downloaded: July 2021)

WISDOM, J.–CRESWELL, J.W. (2013): Mixed methods: Integrating quantitative and qualitative data collection and analysis while studying patient-centered medical home models *AHRQ Publication.* No: 13-0028-EF. https://www.ahrq.gov/sites/default/files/wysiwyg/ncepcr/tools/PCMH/mixed-methods.pdf (downloaded: November 2022)

WEBSITES/DATABASES

[1] CREDITONLINE (2022): *Database.* www.creditonline.hu (downloaded: November 2022)

[2] MAGYARORSZÁG KORMÁNYA (2022): *Közérdekű adatok és információk.* www.kormany.hu (downloaded: November 2022)

[3] WEB OF SCIENCE (2022): *Database.* https://www.webofscience.com/wos/woscc/basic-search (downloaded: November 2022)