INDUSTRY 4.0 OVERVIEW BASED ON SELECTED INDICATORS: THE CASE OF HUNGARY

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ABSTRACT

The concept of Industry 4.0 (Fourth Industrial Revolution) was for the first time presented in Germany as an industrial modernization program. Nowadays, the Industry 4.0 revolution is a highly discussed topic as industrial production is one of the most important economic sectors in the European Union. Due to the lack of skilled laborers in the EU countries, industrial transformation and digitalization seem to constitute necessary evolutionary steps. Current demographic trends and projections of the future workforce composition are showing warning signals. The aim of this article is to introduce the concept of Industry 4.0 (or I4.0) in Hungary– a member of the Visegrad Group and the EU – until 2030. The article will provide the basic statistics regarding I4.0. Based on the available data, the efficiency of the I4.0 policy pillars will be evaluated. Furthermore, possible solutions to problems regarding adopting I4.0 in the Hungarian environment will be listed. .

Keywords: *Hungary; Economy; Industry 4.0.*

JEL Classification: *O14, O33, J11*

1 INTRODUCTION

The predecessors of Industry 4.0 were the first, second and third industrial revolution. The main characteristic of the first industrial revolution (which started in 1760) was the invention of the steam engine and the transition from farming to machine manufacturing. In the second industrial revolution (1900) the use of oil and electricity led to massive industrialization and production. Information technology was used in the third industrial revolution (1960) to automate production. Each abovementioned industrial revolution built on innovations and opportunities and led to more advanced and developed forms of production.

Industry 4.0 or the Fourth Industrial Revolution is a term introduced in 2015 by Klaus Schwab, founder and executive chairman of the World Economic Forum, in the article *"Mastering the Fourth Industrial Revolution"*. Although the term Industry 4.0 originated with the German government ("Industrie 4.0"), the idea of a fourth industrial revolution has resonated with manufacturers all over the world (Fluid Intelligence, 2018).

The interconnection of digital solutions and automation is already referred to in the Hungarian language as **Ipar 4.0**. However, the translation (and its English equivalent) can be misleading, since the Hungarian term clearly adds a manufacturing center to the concept. Manufacturing is an important sector, but Industry 4.0 aspirations require more general digitization efforts (Fülöp, Z., 2018). Industry 4.0 is characterized by the fact that different people and machines can interact effectively with each other with technological support (Juhász, L., 2018).

The challenges and opportunities of the ongoing fourth industrial revolution include technology, like artificial intelligence, 3D (three dimensional) printing, quantum computing, computer generated product design. In any case, the fourth industrial revolution will bring many exciting challenges and benefits, like robotics and technological innovation in general that will lead to the evolution of global industries (Xu Min, D. et al., 2018). *According to Botlíková and Botlík (2020), globalization is one of the key processes and a major feature of the development of the world economy and significantly reflects fundamental changes in the economic policies of the world's leading powers.*

Meanwhile, the estimated positive benefits that could evolve from implementations appropriate to Industry 4.0 activities may deliver a 20–30% rise in the GDP and profitability of the related industrial segments in Hungary (Haidegger, G. et al., 2016).

2 WORKFORCE, HUMAN CAPITAL AND EMPLOYMENT

According to the Hungarian Central Statistical Office, the number of employed people in Hungary was close to 4.5 million in 2017 (more than 82% of the so called "best working age of 25–54 years" were employed). With this result, Hungary was ranked among the best performing countries in the EU[1] (MTA, 2017). Workforce, human capital and employment are closely linked to labor productivity and economic growth. The skills provide an economic value and can lead to increased productivity.

In the literature, there are contradictory findings regarding the effects of 4.0 Industry technologies on productivity, employment and the reshaping of the geographic structure of value added activities. One author says that specifically in the environment of Industry 4.0 in Hungary (economically destructive) job losses can be expected (Szalavetz, A., 2016). Others claim that this can be offset by new jobs and trends and analyses predict an expected increase in labor demand in Hungary in the future (Fülöp, Z., 2018). More information about the efficiency of Industry 4.0 on employment is provided in Subchapter 2.2.

2.1 DEMOGRAPHIC DEVELOPMENT

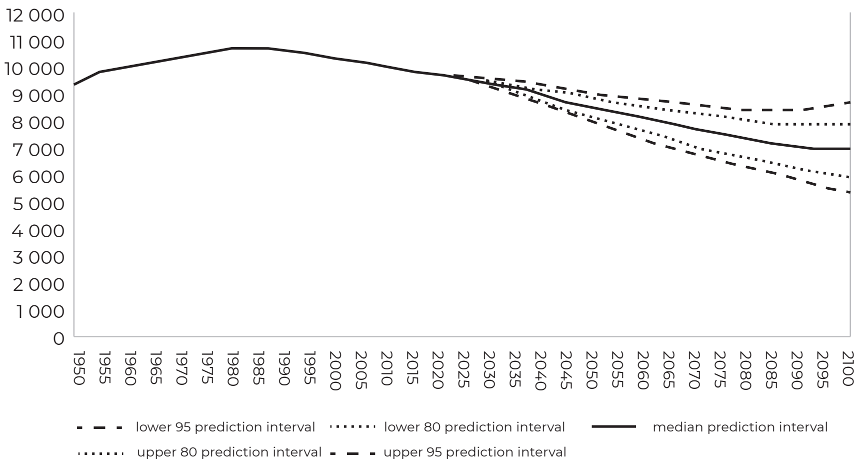
Population evolution directly influences the economic development of a country and vice versa. Because of its importance, the topic of dealing with the demographic situation is included in the article. Current demographic trends and projections of the future workforce composition are showing warning signals in Hungary.

Based on current demographic development and available data from the Population Division of the United Nations database (2019), the population of Hungary is decreasing. The country faces population ageing and increased migration. This slows down the labor supply, which in turn causes a shrinking supply in

1 EU: European Union.

response to increasing labor demand (Fülöp, Z., 2018). In the first quarter of the year 2020, the size of the Hungarian population was approximately 9.6 million inhabitants (see Fig. 1). According to the results of the median prediction interval of the population projection, only 6.8 million people will live in the country by 2100 (a difference of almost 3 million people). This will have an impact on the shrinking labor pool in the population. Based on the current demographic trends and population ageing, the lack of skilled workers in the EU may cause severe problems in the near future.

Fig. 1: »Population size, 1950–2100



Source: author's construction; data: United Nations, 2019

In recent years, the fertility rate in the region has been below the reproductive level. Hungary, together with the majority of European countries, faces population ageing (Tab. 1), which will lead to a decrease in the number of economically active people (the current retirement age was set at 64.5 years in 2020[2]). In developed countries the share of old people exceeds the proportion of young people. One demographic indicator used for expressing the ratio of economically inactive elderly people (typically aged 65+) compared to the economically active popu-

2 Officina.hu: Nyugdíjkorhatár 2020 táblázat férfiak és nök esetén: ki, mikor mehet nyugdíjba?

lation (aged 15–64) is the old-age dependency ratio. The old-age dependency ratio[3] projects increasing levels of economic dependency in European countries in the future. The case of Hungary is highlighted in Table 1. In 2019, there were almost 30 economically inactive people aged 65+ per 100 persons of working age (15–64). The most relevant data from the database of the European Statistical Office were used. The old-age ratio indicator increased in all countries in the period 2010–2019 and this trend is still ongoing.

Tab. 1 » Old age dependency ratio in EU, 2010–2019

EU-27 countries (from 2020)	26.3	26.6	27.1	27.7	28.3	29.0	29.6	30.2	30.8	31.4
EU-28 countries (2013–2020)	26.1	26.4	26.9	27.5	28.2	28.8	29.3	29.9	30.5	31.0
Czechia	21.7	22.3	23.4	24.6	25.7	26.6	27.6	28.6	29.6	30.4
Germany	31.4	31.4	31.4	31.5	31.6	32.0	32.0	32.4	32.8	33.2
France	25.6	25.9	26.7	27.5	28.3	29.2	30.1	30.9	31.7	32.5
Italy	31.2	31.3	32.0	32.7	33.1	33.7	34.3	34.8	35.2	35.7
Hungary	**24.2**	**24.4**	**24.6**	**25.1**	**25.8**	**26.5**	**27.2**	**27.9**	**28.5**	**29.3**
Poland	19.1	19.1	19.7	20.4	21.2	22.2	23.1	24.2	25.3	26.4
Romania	23.7	23.7	23.7	23.9	24.3	25.2	25.9	26.7	27.5	28.1
Slovakia	17.3	17.5	17.8	18.4	19.0	19.7	20.6	21.5	22.5	23.5
Sweden	27.7	28.4	29.2	29.9	30.6	31.1	31.5	31.6	31.7	31.9
United Kingdom	24.6	24.9	25.6	26.4	27.0	27.5	27.8	28.2	28.6	28.9
Norway	22.5	22.8	23.3	23.7	24.2	24.5	25.0	25.4	25.9	26.4
Switzerland	24.7	24.9	25.3	25.7	26.1	26.4	26.7	27.0	27.4	27.8

Source: data: European Statistical Office, 2020b

3 **Old-age dependency ratio** is the ratio between the number of persons aged 65+ (the age when they are generally economically inactive) and the number of persons aged 15–64. The value is expressed per 100 persons of working age (15–64).

the share of old people (60–69 years) is higher than the proportion of children in the youngest age categories (0–15 years). The age structure of the population reflects previous changes in the level of birth rate, mortality and foreign migration. Hungary is one of the countries with a regressive type of age structure (higher rate of older people than the proportion of children). The age structure is very irregular with many significant indentations and protrusions in the population pyramid. The changes in the population structure and the loss of human capital affect the transformation of market requirements.

2.2 THE EFFICIENCY OF INDUSTRY 4.0 REGARDING EMPLOYMENT – LITERATURE REVIEW

The focus of previous research has repeatedly been on the **manufacturing industry** in Hungary – but it has to be emphasized that this is not the only sector Industry 4.0 covers. However, based on the labor market situation, it is currently assumed that the majority of mechanizable processes occur in the manufacturing industry, and this may reduce the number of people employed there (Fülöp, Z., 2018).

According to Ray, et al. (2017), manufacturing technologies (intelligent manufacturing, IoT-enabled manufacturing, cloud manufacturing) may have impacts on manufacturing models, approaches and even businesses.

Stock and Seliger (2016) expect the following trends and developments to create value: "*The manufacturing equipment will be characterized by the application of highly automated machine tools and robots. The equipment will be able to flexibly adapt to changes in other value creation factors, e.g. robots will be working together collaboratively with the workers on joint tasks*".

In this section, the efficiency of Ipar 4.0 regarding employment will be presented in the form of literature review and research findings. Contradictory results of various research studies on the influence of Ipar 4.0 on employment are presented in the literature (see Tab. 2). Some findings are optimistic (Berger, R., 2014), others are pessimistic (Nábelek, F. et al., 2016; Arnzt, et al. 2016). In Chapter 3, the background of the past and current economic situation in Hungary, as well as the concept of National Technology Platform (IPAR 4.0) will be discussed.

Tab. 2 » Literature overview and research findings

Author	Methodology. Geographical aspect	Main results	Attitude to changes
Berger, Roland	Labor market mode-ling, 50% expansion of Industry 4.0 solutions until 2035. Western Europe	1.4 millions of new job positions in Western Europe. The number of people employed in industry firstly increases, then decreases by a total of 5 million. Close to 10 million of new jobs will be created (70% among service companies).	Optimistic
Arnzt et al.	Secondary data anal-ysis. OECD countries	9% of jobs in OECD countries can be automated.	Pessimistic
Rodrik, Dani	Examining the eco-nomic role of industry. Europe	Low-skilled workers were almost completely affected by the disappearance of industrial jobs. Meanwhile, the number of highly qualified workers is increasing.	Rather pessi-mistic
Nábelek et al.	Analysis based on com-pany surveys. It is based on jobs that can be created by automation. Hungary	Loss of 500 thousand jobs positions.	Pessimistic

Source: Fülöp, Z. (2018). Az Ipar 4.0 munkaerőpiacra gyakorolt hatása. Munkaügyi Szemle. 61.

3 DEVELOPMENT OF THE HUNGARIAN ECONOMY (PAST, PRESENT AND INDUSTRY 4.0 ACTIVITIES)

It is very important to highlight that currently Hungarian industrial production is mainly fuelled by car manufacturing, electronics and the food industry. Furthermore, large multinational manufacturers, which ***have the most significant weight in production,*** are able to produce more thanks to recently increased capacity, while mid- and low-level manufacturers are struggling and scaling back production. Agricultural production has always been important and traditional in Hungary's economy, although its role in the economy has steadily declined (Bozsik, N. et al., 2018). Agriculture represented 12% of the GDP in 2018. In both of these areas (industrial and agricultural production), employment and manpower are indispensable. The efficiency of Industry 4.0 regarding employment was mentioned in the previous chapter.

3.1 PRODUCTIVITY BEFORE THE 4.0 REVOLUTION

In 2013, the Hungarian national economy emerged from recession (the economic crisis lasted 2011–2012). During the last years, industrial export has become the most important factor in the Hungarian economic system (Kormany.hu, 2016).
The increase in export was affected mainly by trade in road vehicles, electric machines, food, drink and tobacco, medicinal and pharmaceutical products.

The growth in the period 2009–2015 was largely based on the output of export-oriented international companies. Germany has been the leading trade partner not only for Hungary, but also for other European countries (including Czechia). Consequently, the Hungarian economy is closely connected to the development (rise and fall) of Germany's economy. In addition to changes in manufacturing technology, the concept of Industry 4.0 defines a coherent policy framework aimed at maintaining the global competitiveness of German industry (Kovács, O., 2017).

Among the key foreign trade partners are, as formerly mentioned, Germany (27.4% in 2014) and Austria (5.5% in 2014), followed by the USA and Russia as non-EU business partners (21.9% of the total exports is realized through non-European trade partners).

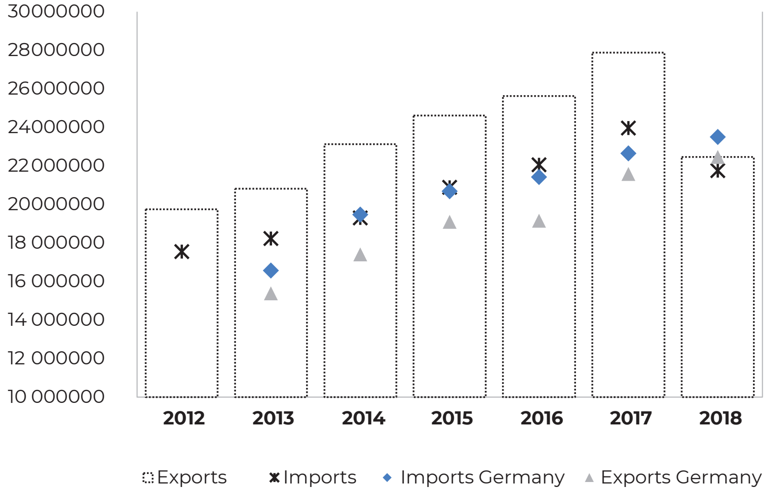
The annual value of imports and exports (unit of measure in thousands of Euro) between Hungary and Germany in the period 2012–2018 is shown below (Fig. 2).

The data were obtained from the Eurostat database *(Database by themes – International trade – International trade in goods – trade by enterprise characteristics – "Trade by partner country and NACE Rev. 2 activity").*

The graph confirms the abovementioned fact that Germany is the leading geopolitical entity (partner) for Hungary in export (27,887,445 thousand Euro in 2017). On the other hand, export to Germany in 2018 (from Hungary) was only 22,460,233 thousand Euro.

In addition, simplifying the regulatory environment would help broaden the export base. The share of exports to EU countries still lags behind regional partners.

Fig. 2: »Imports and exports between Hungary and Germany, 2012–2018



Source: author's construction based on data from Eurostat, 2020a

According to the report published by the National Bank of Hungary, the per capita productivity[4] in Hungary returned to what it was before the crisis in 2011–2012 and has been growing constantly since then. Foreign direct investments have always played a significant role in the development of Hungarian industry since the beginning of the 1990s and by now have turned into the engine of technological development. The shift of production of foreign enterprises (delocalization) to Hungary means job creation and technology modernization (Kormany.hu, 2016).

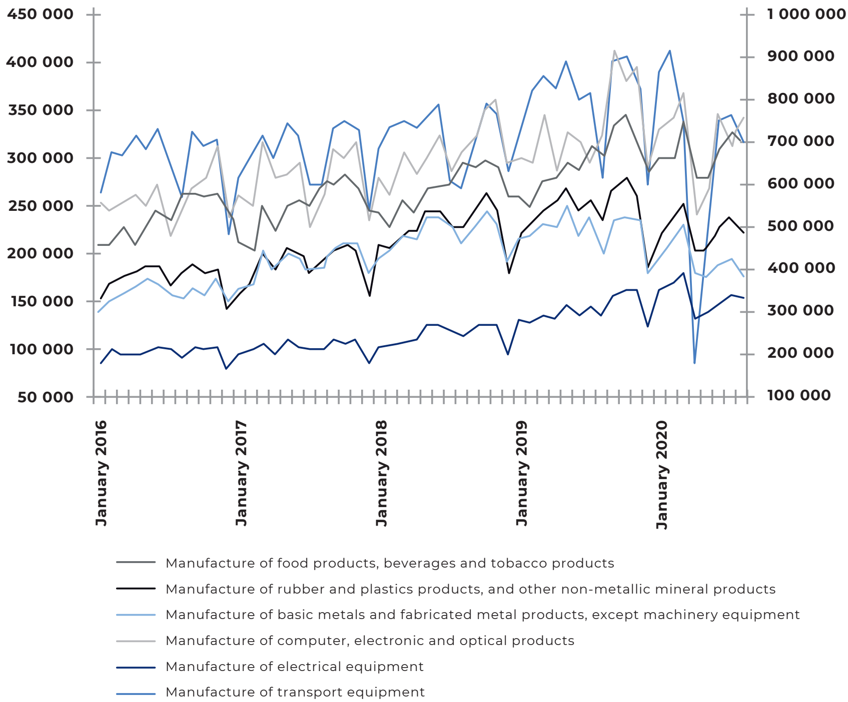
In Figure 3, the value of industrial production by sub-sections is presented. The analyzed period includes the most current values of industrial production by months (from January 2016 until August 2020). The following major subsections of manufacturing have been chosen: *manufacture of food products, beverages and tobacco products; manufacture of rubber and plastics products, and other*

4 Per capita productivity = the value of goods and services produced by one employee.

non-metallic mineral products; manufacture of basic metals and fabricated metal products, except machinery and equipment; manufacture of computer, electronic and optical products; manufacture of electrical equipment; manufacture of transport equipment. In August 2020, the volume of industrial production declined by 2.1% compared to the same period of the previous year (HCSO, 2020). In January 2020 – August 2020 compared to the same period of the previous year, industrial production declined by 11%. Export sales (representing 64% of all sales) fell by 11.6%; domestic sales (representing 36% of all sales) declined by 7.4%.

The item *"manufacture of transport equipment"* has the most weight (28% of the manufacturing output) and was higher by 6.2% compared to the previous year's production (however, manufacture of parts and accessories for motor vehicles declined by 1%). Figure 3 shows a sharp decline in industrial production in the first months of the year 2020 (this may have been affected by the COVID-19 crisis).

Fig. 3: »Value of industrial production by sub-sections, 2016-2020 (million HUF)



Source: data: Hungarian Central Statistical Office, 2020; own processing

3.2 National Technology Platform (IPAR 4.0)

Firstly, it is important to highlight that the promotion of Industry 4.0 in Hungary is primarily led by the government. Like other developed countries around the world, Hungary is also trying to meet the objectives and requirements of Industry 4.0 innovation. When translated and compared to the original "Industrie 4.0", the Hungarian expression "Ipar 4.0" highlights in itself the manufacturing industry[5].

The very first step and idea emerged from the German economy and the state of the German industry, forecasts and the need of state-level innovations in the next decade. In 2013, Plattform Industrie 4.0 (Industry 4.0 Platform) was established, followed by the publication of the industry 4.0 "Future Factories", which has become the European Union's industry-oriented and innovation strategic plan (IEC, 2015).

Implementing the National Technology Platform – a national strategy for reindustrialization of the country – was initiated by the Ministry for National Economy (NGM)[6] and the Institute for Computer Science and Control, Hungarian Academy of Sciences (MTA SZTAKI)[7].

The Industry 4.0 National Technology Platform (abbreviation I4.0 NTP) was launched in the year 2016 in order to reinforce manufacturing, industry and digital transformation (European Commission, 2017). In February 2016, the government developed a reindustrialization strategy plan (so-called **"*Irinyi Plan*"**). The plan outlines the main directions of innovative industrial development in Hungary. In October 2016, the most urgent topics led to the establishment of seven work groups together with the corresponding governmental forums and bodies, which contribute directly to the formation and implementation of the government's strategic goals: strategic planning, employment, education, training, production and logistics, ICT technologies, Industry 4.0 Cyber-physical pilot systems, business model and innovations.

In 2017, working on an assignment received from the Ministry for National Economy, the Platform created a strategic concept material for an Industry 4.0

5 IPAR (feldolgozó ipar = manufacturing industry) .

6 NGM: Nemzetgazdasági minisztérium. Ministry for National Economy.

7 MTA SZTAKI: Magyar Tudományos Akadémia Számítástechnikai és Automatizálási Kutatóintézete. Hungarian Academy of Sciences Institute for Computer Science and Control.

based industry development in Hungary. The main goal of the strategy is to boost the digital transformation in the industry that uses smart tools, and thus conform to the international trends of the Industry 4.0 achievements (e.g., the inclusion of Hungarian companies in international production networks). The pillar structure of the Industry 4.0 development strategy until 2030 is listed below. In addition to the three dimensions of the evolution process (Business, Society, Technology)[8], altogether five pillars have been defined – *digitalization and business development, production and logistics, I.4.0 labor market development, research, development and innovation, I4.0 ecosystem* (Tab. 3). According to highly optimistic scenarios, this goal seems achievable by 2030 (Nagy, J., 2017).

Tab. 3»Pillars of the IPAR 4.0 strategy until 2030

Dimension/ Pillar	Business	Society	Technology
Digitalization and business development	Renewal of SMS business models	Analysis and attitude shaping	Dedicated digitalization investment programs
Production and logistics	Enterprise development and cluster formation	Concentrated strategic projects, supplier programs	Improved efficiency and increased capacities
I4.0 labor market development	In-house company trainings	Practice and theory orientation in I4.0 labor market training from vocational training to graduate and postgraduate education	Infrastructure for I4.0 oriented training and education
Research, development and innovation	New business models, RDI[9] incubation	Reinforcing science, I4.0 RDI programs	Production and related RDI services
I4.0 ecosystem	Digital I4.0 networks	Legislation, standardization, control	Technology and infrastructure development

Source: The Industry 4.0 National Technology Platform Association, 2017

8 In the global trend of Industry 4.0, four major dimensions can be identified.

9 RDI (research, development and innovation)

The National Technology Platform (IPAR 4.0), which serves as a basis, has been expanded based on current strategy plans of the government and the Ministry of Innovation and Technology.

In the spirit of the future vision of digitalization, the Hungarian government has developed a ***"Strategy for Strengthening Hungarian Micro, Small and Medium-sized Enterprises (2019–2030)"***. MSMEs[10] represent the most important basis for the strengthening and growth of the Hungarian economy. Entrepreneurs in this sector create more than half of the added value and employ more than two thirds of Hungarian workforce. In the period 2010–2017, their productivity improvement significantly exceeded that of large companies, and even surpassed the average growth rate of the V4[11] and EU members. The aim of this strategy is the contribution of domestic companies to a sustainable economic growth and increase in the quality of life of Hungarian households.

Recent strategy has seven pillars (Ministry of Innovation and Technology, 2019):

- Creating a business-friendly regulatory and tax environment,
- Improving the business environment for MSMEs and e-government tools,
- Strengthening the development capacity, innovation and digital performance of MSMEs,
- Encouraging access to finance,
- Promoting the internationalization of MSMEs,
- Acquiring the necessary knowledge, strengthening the entrepreneurial culture,
- Supporting generational exchange.
- The Hungarian government together with the Ministry of Innovation and Technology are continuously updating strategies regarding the implementation of Industry 4.0 in the country. The most recent is the "***Artificial Intelligence Strategy"***, approved in February 2020. *"It is expected that the use of artificial intelligence will contribute by 14% to GDP in 2030, what is about 7 billion HUF*[12]*. There are many possible applications, including face recognition, X-ray, lie detection, identification of fault noises on agricultural machine-*

10 Micro, Small and Medium-sized Enterprises (MSMEs), often referred to as Small and Medium-sized Enterprises (SMEs).

11 The Visegrad Group (V4).

12 Hungary Forint (HUF).

ry, the appearance of self-driving vehicles", as minister László Palkovics stated (Kormany.hu, 2020).

3.3 READINESS AND EFFICIENCY OF THE IPAR 4.0 STRATEGY

In Hungary, a breakthrough took place in 2016 with respect to the general level of knowledge about Industry 4.0 that is perceived as important or indispensable from the competitiveness perspective by 71% of industrial companies. This proportion is very favorable even if it is only 66% in the case of Hungarian companies, whereas it is more than 85% in the case of the international ones. This progress is also due to the fact that new solutions are mostly imported, first of all through the intervention of multinational companies (I4.0 Platform, 2017).

To manifest the performance and evolution in digitalization, the components of the Digital Economy and Society Index (DESI) were selected and their results between 2015–2019 shown (Fig. 4). The Digital Economy and Society Index is a composite index published every year by the European Commission since 2014, measuring the progress of EU countries towards a digital economy and society. It brings together a set of relevant indicators on Europe's current digital policy mix. The DESI is composed of five principal policy areas: connectivity[13], human capital[14], use of Internet[15], integration of digital technology[16], digital public services[17]. The index is calculated as the weighted average of the five main dimensions: connectivity (25%), human capital (25%), use of Internet (15%), integration of digital technology (20%), digital public services (15%). The score of the country ranges from 0 to 100. The majority of DESI indicators come from the surveys of Eurostat[18] (European Commission, 2019).

13 Mobile broadband, fast and ultrafast broadband and prices.

14 Internet user skills and advanced skills.

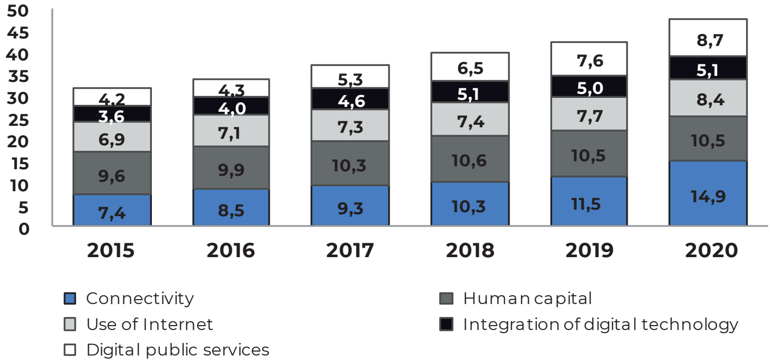
15 Citizens' use of internet services and online transactions.

16 Business digitisation and e-commerce.

17 e-Government and e-health.

18 EUROSTAT: European Statistical Office.

Fig. 4: »Development of main dimensions of DESI indicator, 2015–2019 (%)



Source: author's construction based on data from European Commission, 2019

Hungary performs best in the category *"connectivity"* (14.9 in 2020) (see Fig. 4). However, it has not managed to improve its position in the overall rating. There is still a room for improvement in *"human capital"*, although Hungary has a high proportion of ICT graduates and a close to average share of IT specialists. Hungary is unfortunately among the worst performing EU countries in *"integration of digital technology in enterprises"* (5.1 in 2020) (Nick, G. et al., 2019).

In the literature, several Industry 4.0 readiness evaluation methods can be found. In order to explore the acceptance of the Industry 4.0 concept as well as the current status of the Industry 4.0 implementation both at company and national economy level, the ***"National Technology Platform survey project"*** was implemented in Hungary in 2017. The questionnaire was developed by MTA SZTAKI, which regularly consulted the most active members of the Platform's Strategic Planning Work Group. The main goals of the NTP[19] survey project were to justify the recommendations formulated in the industry development strategy, looking at a 3–5-year horizon (with an outlook to the 2025–2030 period) and to explore the acceptance and current status of the Industry 4.0 concept by companies. The distribution of the respondents by industrial sectors is the following (in descending order): automotive, machinery, ICT, electronics, food, other industry, metal, chemical/ pharmaceutical, logistics and energy sector. Small and micro-sized

19 National Technology Platform (NTP).

companies formed the majority of the respondents by size and 100% Hungarian private ownership generated the majority of the addresses by ownership type.

Indeed, for the purpose of this article, only a selected part of the NTP survey questionnaire has been included. Focusing on the acceptance and implementation of the Ipar 4.0 strategy at the national level, the good news is that in the case of both large and small companies the Ipar 4.0 strategy with its pillars is already in progress. Two small and medium-sized enterprises (SMEs) have declared that their strategy has been implemented.

The individual Readiness Index of companies is divided into six classes (in ascending order): outsiders, beginners, intermediates, experienced, experts, top performers. No top performer was found among the interviewed enterprises[20]. The majority of companies belong to the category *"intermediates"* (38%). These categories come from the VDMA[21] study and have been kept for the sake of comparability. The scoring and weighting methodology was set up by the authors of the National Technology Platform survey project.

The **conclusions** and **main findings** from the survey are that the majority of industrial companies have no Industry 4.0 strategy so far. Although a large number of industrial companies understand the importance of data collection, the rate of those who do this in a comprehensive way is negligible. Most Hungarian industrial companies need to renew their technical infrastructure to ensure developmental scalability (I4.0 Platform, 2017). It is evident that the RDI (research, development, innovation) potential is one of the key tasks in any Industry 4.0 based development strategy. *According to study results by Moeuf et al. (2018), SMEs do not exploit all the resources for implementing Industry 4.0 and often limit themselves to the adoption of Cloud Computing and the Internet of Things.*

Losonci, D. et al. (2019) came with the same conclusions and recommendations as the NTP survey (2017): although the phenomenon of Ipar 4.0 is sprea-

20 To compare the readiness of companies with other developed regions, e.g., in Germany, the share of top performers is evident.

21 The Mechanical Engineering Industry Association (VDMA) represents around 3.300 member companies in the SME-dominated mechanical and systems engineering industry in Germany and Europe.

ding, it has not yet reached the required level in the *technological, organizational* and *human* aspects in companies. Progress is affected just by these three areas. A possible solution for Hungary may be absorbing the *technological know-how* of manufacturing companies. Another obvious tool is to encourage technology transfer by foreign companies (to create channels through which Hungarian-owned companies can learn from leading companies). Losonci, D. et al. (2019) in their survey analyzed leading road-vehicle companies using panel data and found no indication that companies would succeed in realizing one of the great promises of Industry 4.0 – namely – to significantly improve their added value capacity.

4 POSSIBLE SOLUTIONS TO IPAR 4.0 PROBLEMS

In this section, a review of recommendations and attitudes to Industry 4.0 main problems in Hungary will be presented. To provide a comprehensive overview, current experience and future suggestions from the state, companies and experts are listed below.

4.1 STATE AND GOVERNMENT INTERVENTIONS

First of all, the role and contribution of the state in shaping the Ipar 4.0 ecosystem will be examined. Again, the ranking from the "National Platform Survey Project" (2017) was used for the analysis. The survey was carried out in 2017 and no recent data are available. Among the most promising areas of efficient intervention, educational system and infrastructure development received over 80% rating of "*very important*" and "*important*". Other areas – financing, employment policy, legal regulation, regional strategy – are also thought to be the most straightforward. Respondents' expectations in the field of financing highlight two tools – tax reduction and government funding. Supporting less developed regions by the state policy and infrastructural development are generally supported. The potential areas for state interventions and areas where the state can actively help are lack of skilled workforce and their training.

To sum up, conceivable solution for implementing Industry 4.0 could be through the **cooperation between academia** and **industry** because these activities have a strong multiplicative effect on the internal capacities of companies.

The implementation of industry-university collaboration (IUC) is increasingly important for governments, policymakers, researchers and practitioners. The factors that affect the success of IUC are flexibility, honesty, clarity, awareness of current economic, legal, political and social developments. For a successful collaboration, an effective knowledge and technology transfer is important, as well as finding an adequate partner with corresponding interests and goals.

According to Rybnicek and Königsgruber (2019), these recommendations should serve as a useful framework for discussions among practitioners and researchers. Industry can participate in collaboration with academia through internships for students, technology updates, support in establishing laboratories and research projects.

Since the establishment of NTP in Hungary, many public-private partnerships and collaborations have been established between the entities representing industry (companies, universities, other academic circles). It is crucial to ensure a well-balanced representation and involvement of all relevant stakeholders covering the key I4.0 sectors in Hungary. This will bring together stakeholders from different sectors (e.g., manufacturing and ICT) and also small and large business enterprises. Overall, 47% of the surveyed Hungarian companies made use of this IUC opportunity. This may be a cause for hope for the future. Several pilot systems need to be set up in industrial firms in order to enable organizations to manage risks connected to the implementation of new ideas[22].

The tools to achieve results of I.4.0 can be summarized into four main activities (Digital Transformation Monitor, 2017):

- Private sector involvement,
- Bringing together different sectors,
- I4.0 pilot systems,
- Policy strategies.

In the case of RDI (research, development and innovation), results are not positive at all: 38% of the companies haven't launched any innovation in the past 5 years.

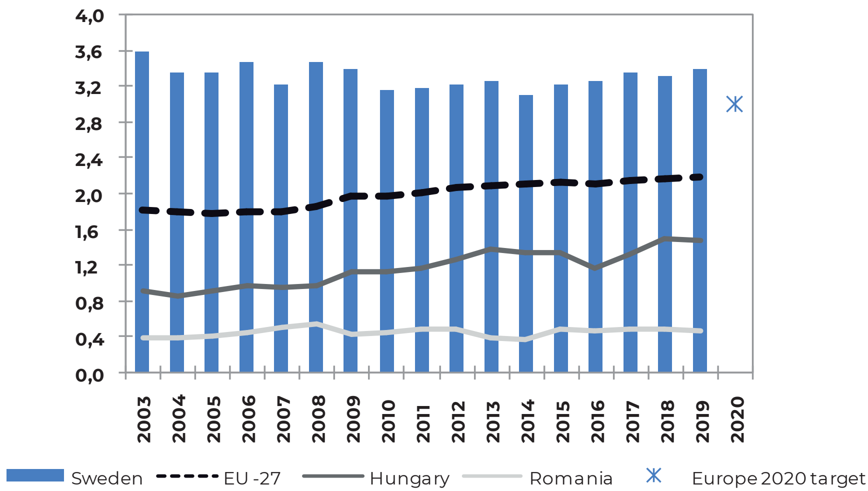
One of the Europe 2020 headline indicators is *Gross domestic expenditure on research and development (R&D).* The aim of the Europe 2020 strategy was to

22 4.0 pilot systems across the country launched in autumn 2017.

increase public and private investment in R&D to 3% of the GDP (see Fig. 5).

Fig. 5 reflects the situation of Hungary, Sweden and Romania compared to the EU-27 average (2.2 in 2019). Sweden was selected as a country with the highest expenditure on R&D (3.39 in 2019); on the other hand, Romania has the lowest expenditure on R&D (0.48 in 2019). Hungary has significantly increased its expenditure on R&D during the period 2003–2019 (0.92 in 2003 and 1.48 in 2019). Hungary does not belong among the worst EU countries. An important consideration arises at this point – could it be that companies do not use the available financial support from the state effectively?

Fig. 5: »Gross domestic expenditure on research and development (R&D), 2003-2019 (% of GDP)



Source: author's construction based on data from Eurostat, 2020c

As already mentioned, the Hungarian government plays an important role in the development of Industry 4.0. The Ministry of Innovation and Technology supports the expansion of Industry 4.0 (through the "***Industry 4.0 support program***"), especially the digital transformation of the **manufacturing industry** and **ICT services** sectors based on smart devices.[23] Industry 4.0 is commonly identified with the digitization of manufacturing.

Robots, cyber-physical systems, big data, the Internet of things (IoT), arti-

23 In 2019, the Industry 4.0 support program contributed by 1.5 billion HUF.

ficial intelligence (AI) networking – all of these are concepts most commonly found in Industry 4.0. They are indeed very important, but at least as important is that digitalization should create new business models. Digitalization resulting from the Industry 4.0 strategy offers and implies various modern technologies. In Hungary, cloud-based services (e.g., for data storage or data processing) are wide-spread – one-third of the respondents that participated in the "National Platform Survey Project" (2017) were using them.

4.2 METHODOLOGY AND DATA ANALYSIS

The nature of this article is informative rather than analytical. Nevertheless, the statistical method of regression analysis was used to calculate the dependence of the variable *Y* ("*production in industry*") on two independent variables *X* ("*producer prices in industry*" and "*intramural R&D expenditures*"). The data were obtained from the Eurostat database.

The linear regression model

A regression equation of the form:

$$Y = X\beta + \varepsilon$$

or

$$Y_i = \beta_0 + \beta_1 Y_i + \varepsilon_i$$

explains the value of a dependent variable y_t in terms of a set of k observable variables in x_t.

Y is a vector of *n* values of the explained variable

X is a matrix of values of explanatory variables with dimensions $n*(k+1)$

β vector β contains the parameters of a linear combination of the variables in x_t

ε vector of *n* values of the random variable

Note that β_0 and β_1 are unknown parameters. We estimated them by the least squares method.

4.3 RESULTS

Please find below the results of the regression analysis for Hungary (Tab. 4):

Tab. 4»Results of the regression analysis for Hungary

Regression statistics	
Multiple R	0.9739
R Square	0.9485
Adjusted R Square	0.9216

ANOVA					
	Difference	**SS**	**MS**	**F**	**Significance F**
Regression	2	124.6097	62.3048	9.2179	0.001
Residual	1	6.7577	6.7577		
Total	3	131.3675			

	Coefficients	Std Error	t Stat	P-values
Intercept	61.9883	216.0996	22.0624	**0.000**
Price	-10.75	2.7338	-8.3863	**0.001**
R&D	0.691	0.3722	5.6755	**0.003**

Source: Author's own calculation from Eurostat data (Eurostat 2020d, 2020e, 2020f).

A linear regression line has an equation of the form $Y = a + bX$, where X is the explanatory variable and Y is the dependent variable. The slope of the line is b, and a is the intercept (the value of y when $x = 0$), where a and b are given by:

$$a = \frac{n\sum_{i=1}^{n} x_i y_i - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} y_i}{n\sum_{i=1}^{n} x_i^2 - (\sum_{i=1}^{n} x_i)^2}$$

$$b = \frac{1}{n}(\sum_{i=1}^{n} y_i - a\sum_{i=1}^{n} x_i)$$

The regression line can be written as follows: $y = 61.9883 - 10.75 * Price + 0.691 * R\&D$. For each unit increase in price, production decreases with 10.75 units. For each unit increase in R&D, production increases with 0.691 units. Regression coefficients (dependent and independent variables) are statistically significant (P-values are < 0.05). R-Squared shows how well the data fit the regression model (the goodness of fit). R-Squared can take any value between 0 and 1. The high value of R Square (0.9485) indicates a good fit for the model.

4.4 COMPANY RESULTS AND EXPERT ANALYSIS

In Hungary, the electronics and automotive industries are at the forefront of the digital switchover. The study by **Losonci, D. et al. (2019)** came to the conclusion that for a successful digital switchover, the opportunities inherent in the technology transfer of foreign companies must be exploited, and that training of Hungarian companies in this field must be encouraged. It is advisable for domestically owned companies to turn to their customers and ask for guidance, to develop according to their needs and learn best practices from them. This process should be further encouraged. The ability of suppliers to innovate can be the key for buyer companies if they are interested in smart products and services. However, this may require taking two simultaneous steps: innovation capacity should not simply be developed, but should be done in the context of Industry 4.0 – this is the only realistic option for the near future. Study results of authors Losonci, D., et al. (2019) are in line with the main findings of the **National Platform Survey Project (2017):** although the phenomenon is gaining ground, it lags behind the desired level in the technological, organizational and human aspects in companies.

The study conducted by **McKinsey (Fine, D. et al., 2018)** came to the conclusion that policy makers could consider pilot programs that allow companies to test automation-driven innovations without risking a penalty for not complying with the existing regulations. One such initiative is the "Regulatory Sandbox" that the National Bank of Hungary seeks to implement to encourage testing in the financial technology industry. Under this scheme, financial technology startups would be encouraged to pilot their product and process ideas on real customers for a limited time – such as offering loans based on a big data-driven analysis of customers' spending habits – without having to abide by certain regulations that would inhibit the testing and implementation of new initiatives. Another example of a program aimed at fostering development of automated products and processes is the track near Zalaegerszeg built to test and develop programming for self-driving vehicles (Fine, D. et al., 2018).

Secondly, the government can sponsor private sector innovation through the use of vouchers that provide financial incentives for research centers and SMEs to explore new ways to apply artificial intelligence, automation technologies to intensify digitization. Monetary support in the form of targeted subsidies and tax allowances for companies to invest in automation technologies and human capital (e.g., retraining programs) could improve the business case for adoption. The government might also consider using financial incentives to attract foreign investment to establish innovation hubs that feature the use of automated technologies (e.g., by providing tax incentives for companies to establish technology based research and development operations). It is also recommended to simplify the requirements for residence and visas for non-EU professionals (Fine, D. et al., 2018).

Another relevant analysis was published by **PwC (2018)**. The research had been focused on automotive suppliers who believe that key success factors are increasing added value and attracting research and development operations to Hungary. This is closely connected to an economic environment that supports innovation and offers favorable tax conditions.

Training of specialists (response to the absence of qualified labor force), supporting SMEs, efficient investments using modern technology and equity financing may also represent breakout opportunities in Hungary.

Efficiency and productivity have traditionally been areas where Hungary's automotive industry has been lagging behind in international comparison. Looking on oncoming auto industry trends, robotics is the technology that will be of strategic importance for more than 60% of automotive suppliers in Hungary within 5 years. In the automotive industry, the innovation activities of suppliers are evidently affected by legislation and social trends. New technologies and data-based operations are closely related to IT systems, so investments in this area in the near future are expected (PwC, 2018).

PwC summarizes how companies may earn extra income and save costs with cost-effective solutions (Tab. 5).

Tab. 5»The positive impact of Industry 4.0 on companies' income and efficiency

Source of income	Lower costs or increased efficiency
New digital products, services, solutions.	Flexible, customized production models.
Big data analysis as a service.	Continuous transparency of processes and product variations. Augmented reality and optimization based on big data analyzes.
Digitization of the current product and service portfolio.	Simultaneous production quality control based on big data analyzes.
Increasing market share of the main product.	Digitization and automation of processes for smarter use of human resources.
Digital I4.0 networks	Legislation, standardization, control

Source: Nagy, J., 2017. Industry 4.0: definition, elements and effect on corporate value chain.

CONCLUSION

The fourth industrial revolution is already on its way and there is no going back. Revolutions are dynamic and fast, and Industry 4.0 will be the answer to the challenges companies and economies are facing. Hungary is also a part of these changes and processes, together with other European countries. Industry 4.0 has both positive and negative impact on employment and the quality of life. As a result of technological progress, some jobs will no longer be relevant and human labor force will be replaced by technology. On the other hand, *according to Botlíková and Botlík (2020), new positions may be created that will require a continuous acceleration of technological adaptability*.

In Hungary, the proportion of industrial companies currently operating a non-upgradable technical infrastructure is significant. Research, development and innovation potential is one of the key targets in any Industry 4.0 based concept. Proactively adopting an automation agenda could assist Hungary in attracting foreign investments that would generate a shift in labor force toward higher value-added jobs. For Hungary to remain an investment destination, it is essential to focus on infrastructure development, a strong educational background and a supportive research, development and innovation environment. The main goal of NTP is to stimulate the exchange of information and development in the key areas of Industry 4.0 and to strengthen the competitiveness position of the national economy. Unfortunately, the development of the Hungarian innovation system and the culture of cooperation are not yet fully prepared for the effective application of this type of partnership model. There is a serious problem with the lack of trust capital needed to communicate between key players.

To sum up, the most important areas business and policy makers should act in are education and requalification, as well as innovation for automation. About 60% of current jobs in Hungary have at least 30% technical automation potential. Assessing automation potential according to employment numbers also indicates that manufacturing, public services, trade and transportation will experience the greatest impact from automation. Strengthening the digital maturity of domestic companies capable of joining global value chains should also be strongly supported.

It is suggested to follow up on this study with a more thorough analysis of data from company surveys, which would provide more rigorous conclusions about the impact of various independent variables on the examined issues. Interesting and well feasible would be case studies analyzing specific companies and their approach to the concept of Industry 4.0. Another object of further research may be the calculation of the preparedness index towards Industry 4.0.

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