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Industry 4.0 in Germany, Austria and Hungary: interpretation, strategies and readiness models

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***Abstract* – Global economy increasingly responds to trends of industrial digitization and start to develop their own digitalization strategies e.i. through application of Industry 4.0 concepts. Thereby, initiatives and developments are often carried out on a company-, industry- or country-level, which can result in a lack of international co-operation and utilization of synergy-effects. To analyse the Industry 4.0 development status on a macro level and to enhance transnational developments, in the first part of this study we introduce the national Industry 4.0 platforms of three EU member states – the frontrunner Germany, the solidly rising Austria and Hungary that is in the process of catching up. Our analysis are carried out in four dimensions: economic background, country-specific Industry 4.0 interpretation, and local platforms as well as initiatives. To analyse the actual Industry 4.0 development status of industrial enterprises and of development platforms, existing Industry 4.0 maturity models form all three countries are presented and compared. Our analysis helped to capture the different phases of digitization and Industry 4.0 in Germany, Austria and Hungary in regard to defined goals and strategies and further of resulting problems with respect to Industry 4.0. Building on our comparison-studies and captured problems, decision makers should be enabled to carry out transnational Industry 4.0 projects and initiatives more effectively.**

Keywords – Industry 4.0, Digitization, Maturity models

I. INTRODUCTION

A. The economics of Industry 4.0

Roland Berger states that industrial production plays a central role in the EU economy, and industry is the main driver of research, innovation, productivity, job creation and export. Industry creates 80 % of the European innovation and 75 % of the exports. Through its relationship with the service sector, industry can be regarded as Europe's social and economic engine. Still, the European industry has lost a lot of jobs in the last decade, while it is facing tough competition from the emerging economy. The ghost of "deindustrialisation" currently haunting most European governments and the European Commission is galvanizing them into action. [1][2]. The contribution of production to GDP at EU level was barely more than 15 % in 2013 (currently around 17 %), which represents a major stepping stone to the US and Southeast Asian industrial regions, and is far from the development strategy adopted in 2012: the target is 20 % to by 2020. All these fact have to be evaluated in the background of the fourth industrial revolution which is already on its way. According to Roland Berger, *"revolutions are fast, disruptive and destructive. And there is no going back. Industry 4.0 will be an answer to the challenges lying ahead."* This has led to the reindustrialization strategy announced by the EU. In its implementation, the Industry 4.0 organisations in the member states, the establishment of which is strongly recommended by the European Commission are deemed to play a key role. The Roland Berger study [1] points out that the Return of Capital Employed (ROCE) is the proper measure of progress both at individual company and country level. ROCE is the

economic index governmental industry development policies may have a direct influence on. ROCE is 15 % on average in Europe. When comparing the different strtegic options we find three basic alternatives (Figure 1):

(1) Automation (not to be confused with Industry 4.0): increases capital employed through investments. Profits increase due to automated activities, with ROCE remaining unchanged.

(2) Obsolescence: investments tend to drop to a level below depreciation due to decreasing profits. Asset turnover increases artificially enabling ROCE to remain constant.

(3) Industry 4.0: industrial policies implemented pursue the main objective of increased competitiveness by growth in value added production. Additionally, high margins and flexible production result in higher ROCE.

Alternatives (1) and (2) are iso-ROCE policies, thus only option (3) represents "good" progress. The second chart of Figure x shows the evaluation of some selected countries' ROCE over the period 2000 to 2014. Germany's outstanding performance in this context is evident.

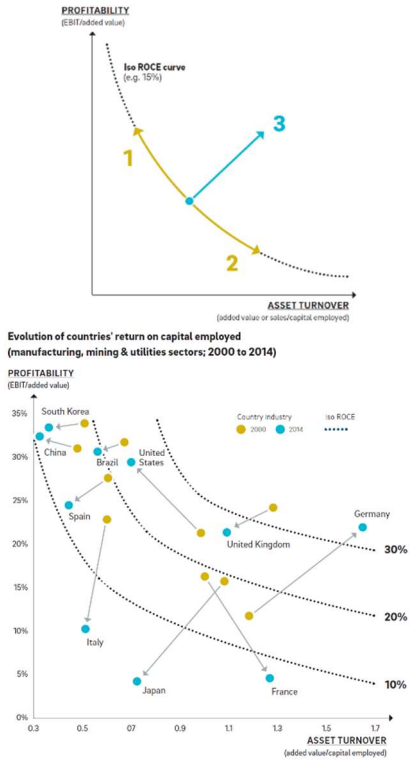

Figure 1: Industry development strategic options [3]

B. Competitiveness and maturity qualified by indices

In the literature different indices and rankings are used to qualify the individual countries' ecosystem in terms of the digitisation status and Industry 4.0 maturity, starting with the most comprehensive and global ones, and arriving at the specific level of the local industrial companies. Thus, the annual Global Competitiveness Report of the World Economic Forum will be discussed first which is a research product on the individual countries' macroeconomic level. The research work done by the EU is represented by the prestigious Digital Economy and Society Index, DESI and the European Innovation Scoreboard, EIS. The most frequently cited source of Industry 4.0 readiness evaluation is the annually published Roland Berger Industry 4.0 Readiness Index [1]-[3]. Although the companies and their digital transformation are always in the focus of Industry 4.0, the issue can only be addressed in conjunction with their environment where the individuals, the social organisations and the institutions of the State have a dominant role. The European Union deals in many aspects with industry policy. It gives directives and defines expectations towards its member states in respect to the digitalisation of economy and society.

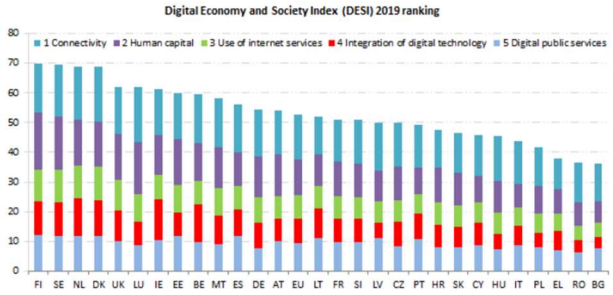

Figure 2. DESI 2019 ranking

It is evident form the chart that Germany and Austria are very close to each other in the overall ranking and Hungary is still lagging behind with a rating under the EU average. We will come back to some of the details when discussing the individual counries.

C. Industry 4.0 readiness models

In the literature, several Industry 4.0 readiness evaluation methods and maturity models can be found. In a recent review of these models, the authors enumerate 15 different maturity models in terms of the method they use, the focus, and also the gaps found in them [4]. These models assess the Industry 4.0 maturity in different dimensions that contain questions or maturity items. The organization or company is evaluated based on these elements by choosing an appropriate level of scale, which contains in general four to ten levels. In terms of these dimensions, the most common ones are the following: strategy and organization, technology, IT, smart factory, smart products, data utilization and employees. In some models, additional dimensions appear, too, for example security policies [5], performance [6] and customers [7]. The number of maturity items vary on a wide scale, e.g. the VDMA's online self-assessment questionnaire [8] contains altogether 18 items, but in another maturity model, the authors present a survey with 65 questions [7].

II. GERMANY – AT THE FOREFRONT OF DEVELOPMENT

A. Economic background

Germany is globally the only country that has managed to significantly improve the industry's ROCE index over the last 15 years, mainly due to its conscious industrial development program. Despite a slight decline in employment (9%), industrial surplus increased to 80%, and industry-generated profits by 158%. Investment and depreciation remained broadly unchanged over the period, while asset utilization rates improved and equipment utilization rose from 85% in 1998 to 95% in 2014. This shows the importance of organization, conscious behaviour and operation. Capital invested, while remaining roughly constant, produces much more than 15 years ago. This is the German industrial wonder.

B. Industry 4.0 interpretation

The solution was the recognition of the potential of Industry 4.0, which was first introduced at the 2011 Hanover Fair, and has since become the supplier of a vast number of innovative Industry 4.0 solutions. In Germany's strategy, Industry 4.0 solutions provide the means to maintain its dominance in global markets and keep its industrial production constant. Consequently, Germany's Industry 4.0 strategy is both defensive - to maintain domestic production, to deal more flexibly with crises on international markets - and offensive - to ensure that expertise and know-how remain in Germany for the export model to function [9]. In Germany, much attention is given to the societal aspects of Industry 4.0: there are various calls, too, focusing on the integration of humans in digital and AI technologies as well as the social impact of those technologies for human life.

C. Platform, initiatives

The long-term strategy developed by the federal government and supported by Plattform Industrie 4.0 is based on five pillars [10]:

- identifying and prioritizing research and innovation topics that ensure the economy's performance, quality of life, and wealth sources;
- promotion of national and international co-operation of knowledge-raising actors in the economy to strengthen their innovation potentia;
- launching of different programs to boost innovation dynamics, with the aim of increasing SMEs' contribution to high R&D costs;
- and creating an innovation-friendly framework and to promote social participation.

A survey conducted by German company managers in 2014 [11] highlighted areas where political support is expected for the Industry 4.0 initiative. On the basis of the results, the continuous training of the qualified workforce, the promotion of international standardization, the creation of competitive data protection laws and the granting of tax incentives for corporate investments are prominent. In addition to Plattform Industrie 4.0, the government has recently introduced a number of significant measures to promote the digital transformation of industry. These include the preparation of SMEs, the provision of technology transfer to small and medium-sized enterprises in connection with Industry 4.0, which is reinforced by the establishment of test laboratories and centers of excellence. The national IUNO project, which focuses on information technology security in the Industry 4.0 process, should also be highlighted. The project aims to address IT security challenges in an industrial application area, thus removing the fears of SMEs of the economic risks inherent in digital transformation.

Germany performs well in most DESI dimensions, especially in the digital skills, where it is among the top performers despite the fact that there is still a lack of ICT specialists in the country. Interestingly, as for the integration of digital technology by businesses, it ranks only slightly above the EU average. Many of the initiatives for the digitisation of the country target SMEs. These include the Mittelstand 4.0 competence centres and the Go-Digital programme.

D. Measurement of Industry 4.0 readiness

The VDMA's online self-assessment questionnaire [8][1] contains altogether 18 items separated into 6 dimensions, where the responding organization has to choose from options corresponding to 6 maturity levels (outsider, beginner, intermediate, experienced, expert, top performer) in case of each question. The dimensions are strategy & organization, staff, smart factory, smart operations, smart products and data driven services. The questionnaire was developed with the aim of self-assessment, thus an organization can check its status regarding Industry 4.0 and take the first step towards digitization.

III. AUSTRIA – SOARING ECONOMY

A. Economic backgorund

On the basis of the relatively low inflation and unemployment rate and the extensive network of social benefits, Austria is among the leading countries in the EU. Following the halt in the economic growth of 2012-2014, the Austrian economy has been growing at an increasing pace since 2015 (1.1% in 2015, 1.5% in 2016 and 2.9% in 2017) and this trend is likely to continue in the coming years [12]. Austria's economic development is driven by increasing industrial production: in June 2017, industrial production was nearly 5% higher than a year earlier. One of the engines of industrial growth is strong export activity (€ 141.9 billion in 2017, up 8.2% from the previous year). Another key to the growth of industrial production is the

competitiveness of Austrian products, which can be explained by the fact that Austria traditionally spends a lot on investment (Austria 23% of GDP in 2016 compared to the only 20% in Germany). According to a survey conducted in 2015, Austrian companies plan to invest 3.8% of their annual turnover on Industry 4.0 solutions on average by 2020, from which they expect an average annual 3.7% efficiency increase and a 2.6% reduction in production costs [13].
In addition to investment intensity, it is also important to mention the high level and continuous increase in R&D expenditure that has been higher than the European Union target of 3% of GDP to be attained by 2020. In 2017, EUR 11.4 billion was spent on R&D, representing 3.16% of GDP, estimated at 3.76% by 2020 [14].

B. Industry 4.0 interpretation

The Austrian definition of the term Industry 4.0 is essentially the same as the German one, with the difference in the approach that social effects of digitalisation are more emphasized. This way, the Austrian Industry 4.0 interpretation often involves topics such as creating new customer values, developing new business models, opening new markets, and changing the structure of employment.

C. Platform, initiatives

The Austrian Ministry of Transport, Innovation and Technology was an active initiator of the Austrian digitalization, recognizing the importance of the Internet in 2014, announced the launch of the Broadband Strategy 2020 (Breitbandstrategie 2020), which aims to make Austria one of the leading ICT countries with spreading the Internet gradually across the country (99% coverage). The government has launched targeted programs such as Production of the Future (Produktion der Zukunft), which has been launched 28 times since 2011, to ensure the long-term competitiveness of Austrian companies and to secure jobs in Austria. The program has strategic objectives such as promoting product innovation (such as supporting the establishment of demonstration and logistics systems), building the research expertise of research institutes (e.g. doctoral and professor scholarships), and supporting European and international cooperation and networks. Under these and similar programs, the Austrian Research Support Office supports € 120 billion annually in initiatives related to Industry 4.0.
The Austrian national industry 4.0 platform is an alliance of important social, economic, political and scientific actors. It was launched in 2015 and focuses on the following activities: ensuring the dynamic development of the Austrian production sector; promoting research, innovation and training; developing highly skilled workforce; and to achieve a high level of employment.

Austria has increased its DESI score only slightly due to a limited performance in some of the DESI dimensions: there is a growing lack of skilled IT workers in the economy and the country performs below average in Connectivity, Use of Internet services and integration of digital technologies. The Digital Roadmap Austria programme was launched early 2017 by the government.In Human capital, however, Austria ranks among the top EU countries, a relatively large proportion of the population has at least basic or above average digital skills.

D. Measurement of Industry 4.0 readiness

In [7] the authors stated that former maturity models are mainly technology focused, and neglect other organizational dimensions, therefore, they present a model, which includes these aspects as well. They define indicators with in 9 organizational dimensions, provide a model with 62 questions (maturity items) measured in 5 dimensions to measure the Industry 4.0 readiness of manufacturing enterprises – used in various cases in Austria. They also present a case study with an Austrian company. In [15], the authors introduce a 10-step Industry 4.0 realization model, which builds on they maturity model and Industry 4.0 strategic guidance [16].

IV. HUNGARY – AT THE GATEWAY TO DIGITIZATION

A. Economic background and Industrial Policy

In order to meet the challenges of Industry 4.0 and taking into account local specificities, Hungary has also developed its own reindustrialization strategy and its complex set of tools, which the government identified as the Strategic Program for Innovative Industrial Development, named after János Irinyi [17]. The ambitious goal of the Irinyi Industrial Policy Plan is for Hungary to become one of the strongest industrial performers in the EU. To attain this goal, innovation-driven economy, highly skilled and active workforce, greater added value, export-oriented value chains, and sustained balanced development are necessary. In line with the European Union's industrial policy, the focus of the Iriny Plan is on machinery and vehicle manufacturing, the health and green economy, the food industry, the defense industry and the ICT sector. The state takes an active role in innovation processes in a number of areas – with orders and investments. The main aim is the following: the GDP growth rate up to 2020 and beyond, should be in the range of 4-5% annually if industrial growth rates remain similar to those of the previous years. To reach the target for 2020 in connection with GDP increase rate – if the rate of growth remains the same as in previous years – an annual increase in industrial production of at least 7% should be achieved.

The implementation of the sectoral development strategies is being carried out by the Irinyi Industrial Policy Plan's 5 horizontal aspects: the application of new and digital technologies, the production of energy- and

material-efficient devices, the elimination of territorial inequalities, the expansion of employment and the efficient use of domestic resources are the central issues. This requires a more conscious entrepreneurial approach, adequate standardization, transparent regulations, and the establishment of predictable, regulated support systems (non-refundable grants or combined loan programs) as a prerequisite.

A significant proportion, 99,1% of enterprises registered in Hungary are SMEs, which is much higher than the EU average. Their role in employment is also higher than in the EU, while their capital strength, export capacity and contribution to GDP are below the EU average. SMEs represent a very significant economic factor at local level, their development is highly important, thus the development strategy has targeted interventions at all stages of the business life cycle (start-up, growing, mature, renewable, declining) and the associated financial resources. Knowledge is greatly appreciated, the accumulation of knowledge in SMEs and their incorporation into high-tech processes is an important objective.

B. Industry 4.0 interpretation

In Hungary, the term Industry 4.0 stands for the fourth industrial revolution based on cyber-physical systems, i.e. the formerly never seen integration of the physical and virtual worlds, and represents a new level of organising and controlling the entire value chain across product lifecycles. This cycle focusses on increasingly personalised customer wishes and extends from the concept to the order, development, production, and shipping of a product to the end customer and ultimately to its recycling, including all associated services.

The foundation is the real-time availability of all relevant information through the integration of all objects in the value chain and the capacity to determine the optimal value flow at any time from the data. The interconnection of people, objects, and systems produces dynamic, real-time-optimised, self-organising, cross-enterprise value-adding networks that can be optimised according to various criteria such as cost, availability, and resource consumption.

C. Platform, initiatives

The Industry 4.0 strategy is based on 5 pillars in Hungary. Although the whole pillar structure is strongly permeated by the government with its stimulating, regulatory activity and the operation of its institutional system, we do not consider the government sector itself to be an independent pillar. The pillars are: digitization and business development, manufacturing and logistics, labour market, research and development and innovation, and the ecosystem. The Hungarian platform was founded in 2016 with the full support of the relevant Ministry, it is operated as a legal entity called Industry 4.0 National Technology Platform Association (NTP). The participants are Hungarian Academy of Sciences' Institute for Computer Science and Control and over 60 economic actors. 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.

Hungary performs best in the broadband Connectivity dimension of DESI. However, it has not managed to improve its position in the overall ranking. In Human capital, although it has a high proportion of ICT graduates and a close to average share of IT specialists, there is room for improvement: Hungary is unfortunately among the worst performing EU countries in the integration of digital etchnology in businesses. Among the government initiatives launched to close the existing gaps, the National Info-communication Strategy 2014-2020, the Modern Enterprises Programme and the recently founded Artificial Intelligence Coalition should be inter alia highlighted.

D. Measurement of Industry 4.0 readiness

In 2016, NTP launched its first questionnaire project that explores the Hungarian Industry 4.0 ecosystem. The first results are published in [19], where the authors present the structure of the questionnaire (containing 99 questions) in detail, and the results in connection to data application in Hungarian organizations. The questionnaire comprises three main parts: firstly, some general questions with the aim of collecting management and statistical data about the organization. Secondly, company level questions about their individual Industry 4.0 chaarcteristics and capabilities (macro level). Lastly, relevant issues regarding Industry 4.0 with respect to the national economy policy, with the aim of having a comprehensive understanding of the situation in Hungary. This way, it provides results related to the Hungarian national economy as well, not only about one organization, in clear difference to the German and Austrian Indusrty 4.0 readiness models. The empirical research conducted when processing the responses aimed to create a map of the Hungarian Industry 4.0 ecosystem. In the paper, the main goal was to explore to what extent specific Industry 4.0 criteria appear in the operation and business model of Hungarian companies. What are the differences in the expectations of individual companies towards the national economy policy? In order to get an adequate picture on both the current and future situation, it is necessary to assess the needs and expectations of the industrial digital ecosystem in terms of strategic economic governance and also to explore the current status of Industry 4.0 awareness, acceptance and implementation at the individual (company, academy,

social organization) ecosystem level and the national economy level, as well. The open attitude of a company for R&D&I cooperation with other actors, the competitiveness potential and conditions, the situation of education and training are also important aspects. The persistent challenges to human resources, the local expectations and effects of industrial digitisation, and above all, the unique Industry 4.0 capabilities of companies are taken into consideration here, too.

The focus of the questionnaire is twofold as previously described: assessing the individual abilities and the level of readiness of enterprises at *micro* level, and gaining a comprehensive understanding of the situation in Hungary at *macro* level. According to the survey, the majority of industrial companies in Hungary understood the importance of this fact: 78% of them had at least partial data collection both on the production and the product usage throughout its life time, primarily for quality control and production statistics purposes. Although data is being collected, in most cases its actual use has not yet become the integral part of the manufacturing and production processes. Based on the survey, Hungarian companies are striving to use the collected product data, but they are yet far from fully utilizing its revenue generating potential through additional services developed on this basis. They are thus ahead of a long familiarisation, technical development and innovation process affecting their entire operation in terms of business model and integration of the new technologies.

V. CONCLUSIONS AND OUTLOOK

In the paper, the authors present the Industry 4.0 approaches in Germany, Austria and Hungary. The countries are investigated and compared through several aspects: economic background, country-specific Industry 4.0 interpretation, local platforms and initiatives, and Industry 4.0 maturity models. The goal for the countries at different levels of digitization is different: for Hungary, the aim is to catch up the frontrunners and join the international value chain. For Germany, the most important thing is to preserve its leading role by following an offensive and defensive strategy at the same time. Austria is in a prosperous phase of development, the main goal for the country is to ensure the dynamic development of the industry. The main benefit of our work is that understanding the differences in the approach and strategies between the three countries as consequences of country specific facts enables us to use the lessons learnt and adapt them in the the project "Centre of Excellence in Production Informatics and Control" (EPIC) funded by the European Union's Horizon 2020 research and innovation programme, in the definition of the business and operational objectives and rules of the said Centre.

As one of the most significant outcomes of our in-depth analysis, we are going to develop our proprietary Industry 4.0 maturity model, to be iteratively tested in a proof-of-concept process with real industrial clients. As the next steps of our research, the position of China, and the other two from the Triad countries – USA and Japan – is planned to be explored in a similar way.

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