Chronicle of a revolution foretold – in Hungary
Industry 4.0 technologies and manufacturing subsidiaries

ANDREA SZALAVETZ[1*]

The paper discusses the impact of industry 4.0 technologies on the value chain position of production. Another purpose is to investigate the impact of these technologies on a sample of ten manufacturing subsidiaries in Hungary. We find that the implementation of industry 4.0 technologies has neither led to the reshoring of production nor of activities that support production. Conversely, local production capacities have been upgraded: advanced manufacturing technologies deployed and integrated with existing systems.

The new technologies have had a complex impact on skills: both de-skilling effects and skill-biased implications can be observed.

Drawing on the empirical findings and on the reviewed literature, two predictions are developed regarding the implications of industry 4.0 technologies. First, the share of value chain activities considered operative (non-core) will increase, and the number of activities global value chain orchestrators consider as strategic (core-competence) will decrease. Second, differences in the value chain position (or rather, in the position along the smile curve) of individual operative activities will become smaller: the bottom of the smile curve will be broader and flatter.

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Manufacturing (processing and assembly) has long been considered a bottom-of-the-smile-curve,[2] operative activity within global companies. Manufacturing needs to be offshored or outsourced in order to minimise the related costs. Recently, however, some scholars (surveyed by *Dombrowski et al.*, 2016) posited that with the advent of advanced manufacturing technologies,[3] referred to as the fourth industrial revolution (henceforth industry 4.0), the

[1] *Andrea Szalavetz* is a senior research fellow of the Institute of World Economics of the Hungarian Academy of Sciences. E-mail: szalavetz.andrea@krtk.mta.hu

[2] The differences in the value added of individual activities comprising the value chain were illustrated by a smile-shaped curve in *Mudambi* [2008] (see figure *1a* later in the text). According to *Mudambi's* model, the value added of activities that precede production (e.g. elaboration of the business concept, creation/coordination of the supply chain, basic and applied research, design), and the value added of post-production activities (e.g. marketing, product related services provision, sales, after-sales services provision) are much higher than the value added of the ones represented in the middle of the curve (processing, assembly).

[3] Advanced manufacturing technologies include among others cyber-physical systems, big data, artificial intelligence, collaborative industrial robots, 3D printing – see *Szalavetz,* 2016.

value chain position of manufacturing might change: manufacturing might become a differentiating factor: a factor of competitiveness.

This statement needs to be scrutinised from the perspective of the competing definitions of industry 4.0. Most definitions lay emphasis on the technological aspects of the new era (*Brettel et al.*, 2014),[4] since the implementation of production systems that represent the new technologies is expected to produce an unprecedented improvement in the performance indicators[5] of production (*Rüßman* et al., 2015).[6]

However, other scholars maintain that the definition of industry 4.0 should not be restricted to the technological novelties (*Bharadwaj* et al., 2013; *Erol* et al., 2016; *Kagermann* et al., 2013). The real novelty of the industry 4.0 era is better captured by analyses that adopt an organisational or a business model approach. According to these approaches, the most important attribute of industry 4.0 is that the new technologies make it possible for the orchestrators of global value chains (GVC) to control the whole value chain in an unprecedentedly integrated manner – provided that they adapt their organisational structure to the requirements of the new technologies.[7] The coordinators of GVCs will be able to monitor, provide product-related services and further develop their products throughout the whole life

[4] In the conceptual paper that introduced this empirical one (*Szalavetz*, 2016) I also used a *technological* definition drawing on *Monostori* [2015]: "…production takes place in smart factories, in other words, cyber-physical production systems are implemented. New technologies (for instance: nanotechnology, laser technology, industrial biotechnology, 3D printing, artificial intelligence) and new materials are used, and these latter have better physical features than the prior ones."

[5] For example, in the capacity utilisation rate, in the accuracy of processing, and in other qualitative operational performance indicators, such as lead-time and flexibility, and in costs.

[6] The title of this paper is paraphrasing *Gabriel García Márquez's* novel, suggesting that contrary to the other industrial revolutions that were identified as such ex-post (*Freeman–Louçã,* 2001), the fourth industrial revolution was foretold (for example *Bermann,* 2012; *Kagermann* et al., 2013; *Manyika* et al., 2013). This leaves the still undecided debate open, whether the experienced changes are in fact revolutionary or only incremental.

[7] There is a related, rapidly expanding literature that addresses the organisational consequences of digital transformation. More specifically, this stream in the literature is concerned with the specifics of the organisational changes that are considered necessary to make corporate organisations aligned with the requirements of the digital era. It is investigated, for example, how organisational silos could be bridged, across-silo collaboration and cross-functional business strategy implemented. How should the IT function be redesigned so that it becomes integrated with (rather than subordinated to) other business processes: how should a digital business strategy designed and corporate organisation transformed accordingly? – see for example: *Agarwal–Brem* [2015]; *Bharadwaj* et al. [2013]; *Porter–Heppelmann* [2015].

cycle (*Erol* et al., 2016; see also *Porter–Heppelmann*, 2014, 2015) and they will gain competitive advantages from business model innovations.

In brief, according to this latter perspective, the revolutionary aspect of industry 4.0 is not the enhanced production capability originating from the digital transformation of manufacturing but rather the competitive advantage originating from the digital transformation of business as a whole (including the business model).

These competing definitions constitute the point of departure of this paper. We investigate *Dombrowski et al.'s* [2016] cited prediction about the changing value chain position of manufacturing from the specific perspective of manufacturing subsidiaries in 'factory economies' (*Baldwin*, 2012).

If the fourth industrial revolution really makes production activity a factor of competitiveness, in other words: if industry 4.0 is not only about a temporary competitive advantage gained from the costly modernisation of the production system, but *production itself moves upwards from the bottom of the smile curve*, then the factory economies that are able to keep the production activities that had been offshored to them, and preserve also the related advanced support activities, i.e. their prior upgrading achievements – will have uniquely favourable prospects.

If however, industry 4.0 also transforms headquarter functions (i.e. besides producing really spectacular improvements in the performance indicators of production, industry 4.0 is rather mainly about *the digital transformation of business*), then a conclusion about eventual changes in the relative value chain position of manufacturing can be drawn only by examining, in parallel, the moves along the smile curve of all business functions and activities that comprise the value chain.

Drawing on an overview of the literature and on interviews with local manufacturing subsidiaries, this paper aims at uncovering the impact of industry 4.0 technologies on the value chain position of production, and on the upgrading of the surveyed manufacturing subsidiaries.

Corporate interviews can, evidently, provide no clear and direct answer to the former question. Moreover, we cannot even claim that the interviews provide solid answers to all the questions raised in the theoretical paper (*Szalavetz,* 2016) introducing this research. For instance, nowhere near enough time has passed to clearly state that the reshoring of production activities to home countries has not happened.

Consequently, the results of interviews about the diffusion of, and the first experiences with industry 4.0 technologies permit only hypothesis development and conceptual analysis of

Dombrowski et al.'s [2016] prognosis that technological progress will prompt changes in the relative value chain position of production.

The remainder of the paper is structured as follows. This introduction will be followed by a brief overview of the related literature. Next, the research method will be presented and the sample of the surveyed companies introduced. Following the presentation of the results, the paper concludes with a conceptual analysis and with hypotheses about the eventual changes in the value chain position of production.

Theoretical background

The topic of technological revolutions can be associated with virtually all strands of (international) economics and business. The theories that are the most relevant for this research address the factors that determine the diffusion of new technologies and the impact of technological development on the structure of employment and on the skill-set required by employers.[8] Furthermore, the literature discussing the tertiarisation of manufacturing, i.e. the integration of production and service activities, and the global value chain literature, more specifically, the stream that focuses on subsidiary upgrading versus the charter loss of local subsidiaries, and finally, the literature that investigates the attributes of industry 4.0 technologies and their impact on business are also closely connected to the question at hand.

Here, we will only highlight some conclusions from the above-mentioned directions of the literature.

An important finding of the literature discussing the diffusion of new technologies is that this process has considerably accelerated over the past century (*Comin–Hobijn,* 2010). Accelerating globalisation is the key explanatory factor of enhanced technology diffusion, since international trade and foreign direct investment are not only the main drivers of globalisation, but also important channels of technology diffusion (*Eaton–Kortum,* 2001; *Keller,* 2004). Nevertheless, technology diffusion is not automatic: successful technology absorption requires indigenous technology development efforts by the recipients (*Cohen–Levinthal,* 1990; *Fu* et al., 2011). Altogether, the lags with which new technologies are adopted across countries is seemingly diminishing: new technologies are adopted increasingly rapidly also in peripheral economies, far from the countries where innovative activity is

[8] This latter topic was discussed in my previous theoretical paper (*Szalavetz*, 2016)

concentrated.[9] If however, the intensive margin of technology adoption is examined, cross-country differences are much larger. *Comin–Mestieri* [2013] showed that even though cross-country differences in adoption lags (extensive margin of technology diffusion) have spectacularly diminished, if the penetration rate of new technology (intensive margin) is examined, i.e. the share of economic actors that have adopted the new technologies and the intensity of technology use, cross-country differences have rather widened in the 20th century. According to the cited authors, cross-country differences in the intensive margin of technology adoption account for a large share of the differences in countries' income levels.

The title of *Comin–Mestieri's* paper [2013] (If Technology has arrived everywhere, why has income diverged?) recalls a classical theoretical thesis, the theory of appropriate technology selection (*Basu–Weil*, 1998). According to this theory, countries' selection among competing technologies is determined by their relative factor endowments.

These theoretical arguments are particularly interesting for our topic. In our case the question arises: what is the time lag in middle-income factory economies, of adopting the most advanced manufacturing technologies? Frontier technology may not be appropriate for the current factor proportions and especially at the current level of human capital stock in these countries. If technology is not appropriate, nevertheless it is widely used in selected segments of the economy that are characterised by a high share of foreign equity, what explains foreign investors' technology transfer?

Another topic that is closely related to our research is the integration of manufacturing and service activities (the servitization of manufacturing). It is not a new phenomenon: it can be observed both at the input- and the output side[10] for a long time (*Pilat–Wölff,* 2005; *Szabó,* 2006; *Tomlinson,* 2000; *Vandermerwe–Rada*, 1988). Nowadays the servitization of manufacturing is accelerating: 'products' that used to be the basic unit of output in manufacturing firms have long been replaced by 'bundles of products and services', 'product–service systems', or 'integrated solutions'. In the industry 4.0 era (in certain industries) a new term signalises the strengthening of the servitization trend: the emergence of the business model of a 'product-as-a-service'. In this model, a sales transaction does not cover the

[9] Technology generation is, however, still very much concentrated in a couple of advanced economies (*Eaton–Kortum*, 2001), and it is still true that few countries can effectively approach the world technology frontier (*Eichengreen* et al., 2013).

[10] Manufacturing uses more and more services and a greater variety of services are integrated in, or accompany and add value to products.

ownership of the product, thus the buyer pays only for the functionality of the product.[11] In other words, the product is the platform of the related services.[12]

On the input side, one of the key technological novelties that reflect the unprecedented development of IT supporting and controlling manufacturing is that smart production systems can take autonomous decisions (without human intervention). Manufacturing activity is controlled by adaptive, self-organising and self-optimising systems that are also capable of self-learning due to inbuilt artificial intelligence (*Váncza et al.*, 2011). Another, less frequently mentioned but just as significant novelty is that ubiquitous information technology has radically increased the integration and transparency of activities along the value chain, thus the coordination and control of value chains have become easier. These latter activities are typically headquarter functions, similarly to systems integration. Applications supporting business decisions – another corporate centre function – have also rapidly spread. This is an important new development in an age, when the costs of integration and coordination have increased for decades due to the increasing complexity of the value chains (see: *Larsen et al.*, 2013 for an overview).[13]

Lastly, another line of the literature worth mentioning here addresses the evolution of subsidiary mandates, and analyses the factors that influence this evolution. The relevant literature abounds in case studies about subsidiary learning and about the upgrading of

[11] For example, it is not the price of the product the customer pays, he/she pays (a predetermined fee) rather for the improvement of the performance indicators (efficiency increase, cost reduction) that occur as a result of implementing the given solution (*Iansiti–Lakhani*, 2014; *Lacy–Rutqvist*, 2015). Similarly, sales transaction is not about ownership transfer, if customers purchase cloud-based IT services. These services exempt customers from investing in (the ownership of) high-performance servers and data centres. The most famous example of product-as-a-service is the performance-based pricing of the air-plane engine of Rolls-Royce ('power by the hour', i.e. based on the hours flown).

[12] The term platform refers, on one hand, to the possibility of product lifecycle management and incremental development using product embedded information technology. On the other hand, it refers to the phenomenon that not the product itself is valuable for the buyer but the related services, for example the data extraction and business analytical solutions embedded in the production equipment (*Porter–Heppelmann*, 2015).

[13] In a previous study (*Szalavetz*, 2013), I referred to the services that contribute to the integration and coordination of geographically dispersed value adding activities, as *value chain integration services*. These services are on the input side of manufacturing activities, and include corporate- and value chain-specific IT and logistics services, services related to supply chain development, organisation development, technical support for subsidiaries, etc.). These services represent a new, third category, in addition to (a) the services that support the core activity (logistics, human resource development, R&D and design, testing, etc.) and (b) product embedded services.

‘entrepreneurial subsidiaries’ (*Birkinshaw*, 1996, *Birkinshaw–Hood*, 1998; *Contractor et al.*, 2010; *Manning et al.*, 2008). These papers demonstrate that it is possible to extend the range of locally performed business functions and activities. They underscore that the division of labour within the global company is not rigid: manufacturing subsidiaries can gain responsibility for advanced, sophisticated tasks that are more knowledge-intensive than their previous responsibilities and generate higher value added.

The changes, however, are not one-way: the extension of responsibilities can be followed by the loss of certain mandates. Changes in the external environment, for example

- a downturn in the business cycle, which prompts parent companies to consolidate the value chain;
- if a competitor acquires the parent company;
- if the parent company decides to change its business model;

  or if – and this is the most relevant for our topic:
- new technologies emerge that represent a radical change compared to the previous technological paradigm – may provoke fundamental changes in the functional division of labour within the global company (Cano-Kollman et al., 2016; Dörrenbächer–Gammelgaard, 2010; Gereffi, 2014).

Research method and corporate sample

Since the research questions – firms’ first experiences with industry 4.0 technologies – require qualitative investigation, an interview-based method seemed a suitable approach. Selecting the sample of companies to be interviewed, my point of departure was Comin–Mestieri’s [2013] cited finding, that there are significant cross-country differences in the penetration rate of new technologies (in the intensive margin of technology diffusion). In Hungary, for example, the situation is not very positive: according to the Digital Economy & Society Index (DESI, 2016) of the European Commission, Hungary ranks twentieth out of the EU-28 Member States in terms of digital performance. One of the DESI Index dimensions Hungary scores worst on – much below the EU-average – is the ‘Integration of Digital Technology by Business’.

In light of these statements, it seemed appropriate to look for local manufacturing subsidiaries of global companies to be interviewed: they are the ones that account for the diffusion of advanced manufacturing technologies in Hungary. I focused on industries where industry 4.0 technologies are the most relevant and widespread: automotive industry, electronics and machinery industry (PWC, 2014).[14] I selected information-rich cases, referred to by *Patton* [1990] as a purposeful sampling method. The cases of the companies in the sample are unique, they cannot be generalised, but their experiences promise insightful observations about issues related to this research.

The interviewed companies have been selected from two databases: the articles and case studies published either in the journal called *Techmonitor* and the related website (see: http://techstorym2m.hu), or in the journal called *Gyártástrend.* The managers interviewed were asked to answer open-ended questions based on a previously composed interview protocol. The written questions were led up by questions constructed on the basis of the *Techmonitor-/Gyártástrend* case study of the given company, and by other company-specific questions, related to information gained from the given company's notes to the financial statement or from its website.

The first group of questions inquired about the industry 4.0 solutions implemented by the given companies; the level of production automation; the specifics of their recent technological investments; and the key novelty of the new technologies – as perceived by the managers interviewed. The next group of questions investigated the drivers and motivations of industry 4.0 technology implementation. Lastly, I inquired about the impact of new technological solutions on employment and on the nature of work, on corporate performance indicators and on the position of the given subsidiary within the global company. I asked, whether the implementation of the new technologies prompted any changes in the responsibilities of the subsidiary, whether there was an example of a prior upgrading achievement that had vanished as a consequence of industry 4.0 technology adoption (if yes, what specifically?), or, conversely, whether the new technological solutions have rather opened up new opportunities for upgrading.

As the investigation was anonymous, only a couple of aggregate data will be provided about the composition of the sample. Interviews were made with ten manufacturing subsidiaries in the automotive (n = 5) and electronics industries (n = 4), and with a local machinery subsidiary of a global multi-divisional company. The companies interviewed are large: with an average number of employees of 1,239 in 2015, and average turnover: € 305 million (n = 9). They are export-oriented: 96 percent of the turnover comes from export (n = 9). All the

[14] According to the cited PWC study, the pharmaceutical and chemical industries are also among the intensive users of industry 4.0 technologies.

companies have been operating in Hungary for a long time, on average for twenty-one years in 2016.

Results

Industry 4.0 technologies at the subsidiaries in the sample

The experience of the companies in the sample provides convincing evidence that local subsidiaries are the main drivers of the diffusion of new manufacturing technologies in Hungary. The cases of the surveyed companies, and other cases in the two databases demonstrate a rapid diffusion of industry 4.0 technologies in Hungary, and also an intensive use of these technologies. This overall positive picture is, however, partly due to a biased sample selection.

The surveyed companies are not only intensive users (and early adopters) of industrial automation solutions, RFID technologies, cyber-physical systems and intelligent decision support systems. They are, to some extent, also *producers* of the technology, as local experts participate in the customisation and in the related adaptive development of the cyber-physical production systems. Subsidiary engineers take part in the programming of industrial robots and in some cases they also undertake corporate-level software development tasks.

Nevertheless, the interviews have also made it clear that the observed speed and scope of technology diffusion and intensity of use cannot be solely explained by a biased sample selection. The managers interviewed called attention to two additional factors. The first one is the gradual and cumulative nature of industry 4.0 implementation. Switching to industry 4.0 is a long *process*, there is no such thing as one single investment decision for ‘transition to industry 4.0’. A key principle applied when designing the new technological solutions was that they should be compatible with the existing production systems, so that the functionality of existing systems should not be endangered by the automation and digitalisation of selected processes, and by the deployment of industrial robots, sensors, data extraction solutions and smart algorithms that control production. This makes the integration of new technologies in the production system easier and cheaper: there is no need to implement large-scale greenfield investments. Note, however, that the most comprehensive industry 4.0 systems (pilot applications) have been implemented at new greenfield facilities built to expand production at some companies in the sample.

The compatibility of industry 4.0 technologies with legacy systems is favourable for Hungary, as a factory economy. If existing production facilities can be developed gradually by integrating new technological solutions into the existing systems, parent companies would not necessarily consider the issue of location (whether to reshore production): this question would immediately arise if the deployment of industry 4.0 technologies required large-scale greenfield investments.

Another issue emphasised during the interviews was that the technological solutions labelled as industry 4.0 are in fact not that radically new as business press articles on the subject suggest. In the automotive industry, the traceability of the products, product parts, and of all components of the production process has long been a standard rule.[15] Computer-operated production equipment, connected machines, simulations used for process development, virtual product design and development cannot be regarded unprecedented novelties either.

Nevertheless, it is new that the price of industrial robots has significantly decreased, which promises good return on investment even in low-wage locations. Another novelty is the emergence of collaborative industrial robots (contrary to conventional robotic applications where robots are fenced, i.e. completely separated from human workers, collaborative robots are not locked away but share a common work space with human operators). According to some interviewees, collaborative robots are expected to significantly reduce the number of jobs on the shopfloor (in certain physical activities).

The real novelty of industry 4.0 technologies is, however, the enormous amount of data that can be extracted about various parameters of the production process, as this has radically transformed: enhanced and optimised a number of business functions, including quality control, production scheduling, maintenance of the production equipment, logistics, etc. As for quality control, for example, nowadays there is no need to pick product samples and inspect their quality parameters to uncover potential defects. There is no need to examine defected products and try to find the causal relation between defects and eventual deficiencies in the production process. Data are collected about every single product, every processing step, and about the condition (e.g. the potential degradation) of the machines and tools involved in the production process. These data are processed by the computing algorithms that are integrated in the cyber-physical production system. Big data analysis has produced qualitative changes: it has become easier to understand the root causes of production problems and provide rapid feedback.

[15] Producers have long been using track and trace systems to be able to identify and locate potentially faulty items in the supply chain that could pose a hazard to consumers.

Another novelty is the unprecedented computerised integration of production (i.e. of heterogeneous production equipment controlled by a variety of software applications): this has made the production process much more transparent than previously.

Altogether, the surprisingly intensive use (among the interviewed companies) of industry 4.0 technologies can be explained by the fact that 'industry 4.0' builds on *already existing solutions,* it improves, unifies and supplements them, and (in some fields) it brings them to the next level.

A third explanation of the rapid extensive and intensive diffusion of industry 4.0 technologies needs to be mentioned, beyond the ones told during the interviews. Digitalising production is much easier, faster and cheaper than digitalising business (shifting to a digital business model, i.e. transforming the framework of competition). It could even be claimed that it is easier, faster and cheaper to transform production units in 'factory economies' into industry 4.0 pilot applications (at least in the case of actors that operate in segments that had been modernised by foreign direct investment and are characterised by a high share of foreign equity) than to transform the companies in 'headquarter economies' so that they fulfil the requirements of the digital age: introduce new work models, new organisational structures and transform their business models (see the case studies by *Agarwal–Brem* (2015) and *Iansiti–Lakhani* (2014) about the transformation of GE, and *Burmeister* et al., 2015; *Porter–Heppelmann,* 2014, 2015 on digital transformation).

Motivations regarding the adoption of industry 4.0 technologies

According to the corporate interviews, when investing in industry 4.0 technologies, in most cases, the surveyed companies did not act according to a predetermined 'digital strategy'. The purpose of investments was rather to find a solution to a specific technological problem. Examples include system malfunctions, machine failures, unplanned shut-downs, poor cycle times, earlier-than-expected tool wear and a shorter than expected lifespan of tools, excessive number of product defects, long changeover time, poor process stability, inefficient process scheduling and bottlenecks in production.

Some managers emphasised other (non-technological) factors, namely that the new requirements set up by customers in terms of quality, deadline and flexibility were so high that they could be fulfilled only by radically transforming the production system and introducing digital solutions, e.g. a real-time control of the production process.

Others mentioned the increasing complexity of production as a key motivation for introducing industry 4.0 solutions. The rapid expansion and diversification of production reduced the transparency of the system, which provoked multiple problems. In order to prevent the accumulation of problems, the implementation of IT solutions (big data analysis, optimisation of multiple parameters, capacity planning and production scheduling software) proved indispensable.

One of the companies gave a surprising answer to the lack of adequately trained workforce, which is a common problem across the sample. According to the chief executive officer interviewed, it was mainly the shortage of labour that motivated the deployment of collaborative robots. Another reason was the significantly reduced price of this new generation of industrial robots, which promised unprecedentedly favourable returns on investment. Conversely, other managers interviewed maintained that hiring additional workers is still more cost-effective than automating production.[16] New technologies have been introduced not to replace workers, or solve the problem of labour shortage, but rather to enhance workers' capabilities. The referred solutions reduce the expensive training period of new operators and minimise the possibility of human error. One example is the introduction of advanced process control solutions, a digital supervisory and information provision system that support operators' compliance with the technical specifications of the manufacturing process.[17]

Two other generally mentioned objectives, which the surveyed firms tried to achieve by implementing industry 4.0 solutions are operational excellence and productivity increase. As one interviewee noted: "*The implementation of automated optical inspection technology and production planning software will boost our productivity to reach 95 percent of the respective indicator of our owner's manufacturing subsidiary in Germany."*

It is worth noting that the objective of reducing costs was never mentioned explicitly. Even if unit labour costs decreased[18] as a result of technology adoption, the purpose of investing companies was not the reduction of costs, rather the *increase in cost efficiency*. As the main

[16] This is obviously a function of technology: the cost effectiveness of automation depends on the features of the given activity and on the possibility/ease of labour replacement by robots.

[17] Another example is the use of augmented reality glasses that provide process instructions. The companies in the sample have not introduced this technology yet, though some managers interviewed mentioned this technology as one that may be introduced in the future to enhance physical operators' capabilities.

[18] As a result of production expansion and the relocation of new tasks to Hungary, the number of employees has rapidly increased at the surveyed companies over the past couple of years (average employment increased by 20 percent between 2012 and 2015). Consequently, the labour-saving effects of industry 4.0 technologies can be observed only in relative terms.

positive impacts of cyber-physical systems are manifested in adopting firms' improved resource efficiency and optimised production, the goal of enhancing cost efficiency was achieved by the surveyed companies.

The effect of industry 4.0 technologies on employment and on the upgrading of the Hungarian subsidiaries

The interviews have made it clear that although industrial automation solutions indeed reduce the unit labour input of production, industry 4.0 technologies are not about saving labour, but rather about achieving operational excellence. When investigating the impact of the new technologies on employment, it should not be forgotten that advanced manufacturing technologies transform the activities of engineers as well. For example, some activities that are based on engineers' routine and on their prior experiences will be automated, including production organisation, production planning and scheduling, capacity planning, maintenance scheduling.

The findings of the literature on the effects of industry 4.0 technologies on the nature of work and on the labour market (discussing whether the recent technological progress is skill-biased or just the contrary) are quite ambiguous. Corporate experiences were a good illustration of this ambiguity.

The experience of the surveyed companies illustrated, for example, that new technologies will increase demand for a workforce capable of carrying out knowledge-intensive, complex tasks (*Acemoglu–Restrepo,* 2015; *Autor,* 2015). As one of my interviewees stated: *"Daily production reports are not prepared for the management (for general or production managers, or process development engineers) any more, they are rather used by the operators."*

The first experiences of the companies in the sample also confirm that new technologies will make some components of skilled employees' knowledge redundant. In other words, what most authors maintain, namely that automation will affect not only low-skilled, physical activities, but some routine knowledge work will also be automated, and smart algorithms will take over selected knowledge-intensive activities as well (*Chui* et al., 2015; *Frey–Osborne,* 2013)[19] – was confirmed. One example is production scheduling that used to be carried out

[19] A related thesis in the literature is that the labour market will be increasingly polarised with demand remaining significant for low-skilled, standard activities. At the same time, medium-level routine activities will gradually disappear, and demand for outstanding expertise and qualifications will strongly increase (*Acemoglu–Autor,* 2011; *Degryse,* 2016; *Hirsch-Kreinsen–ten Hompel,* 2015).

based on production engineers' routine and accumulated experience. Another skill that has become obsolete is the ability to prepare summary production reports based on the analysis of daily production data. Smart algorithms have taken these, relatively high-skilled activities over.

In other cases, smart systems have not taken the given activity over, but have significantly simplified the related knowledge work. The analysis of production data has become easier: smart algorithms prepare the primary evaluation of massive amounts of production data. These algorithms identify 'nodes' and 'patterns' which should be observed and considered when planning production and capacities, and when taking maintenance scheduling decisions.

3D visualisation techniques have enhanced new product design. The virtual representation of the production system has enhanced operational transparency and simplified production control. Process supervisory techniques combined with advanced visualisation solutions facilitated blue-collar employees' compliance with the technical specifications of the assembly process. The flipside of the coin was an overall improvement in process discipline and a reduction in the defect rate.

Examined from another angle, industry 4.0 technologies can be considered skill-biased, since their operation and maintenance requires employees' absorption and mastering of these technologies. According to one informant, one engineer was fired for being unable to make the necessary transition from experience- and routine-based production scheduling to a task execution determined by the results of the newly implemented computing algorithms.

As for the relation between industry 4.0 technology deployment and the upgrading/downgrading of the local subsidiaries, the interviews produced ambiguous results. There were no examples for the loss of subsidiary mandates or for the reshoring of activities to the host country. Just the contrary: there were abundant examples of the location of additional production activities to Hungary. Nevertheless, according to the interviewed managers, the causal link between new technology deployment and further relocations to Hungary is not obvious. According to a consensus finding of several managers interviewed, "*new relocations to Hungary have been going on for years. Similarly, production technology is being developed continuously. The adoption of industry 4.0 technologies is, in this sense, 'business as usual': part of the ongoing organic development process.*"

Elsewhere, the expansion of production required the construction of a new, greenfield facility. Consequently, it seemed evident that the new facility should be equipped with the most up-to-date technological solutions. In some instances, the management of the Hungarian subsidiary initiated – using the budget available for the subsidiary to use autonomously for investment, or using the amount of government support awarded in the framework of policy programmes supporting companies' technology development initiatives – that cyber-physical solutions should be implemented to optimise certain parameters of the production process. Other examples of subsidiary-driven investment included the digitalisation of certain manufacturing processes and their connection to the network, and the implementation of business analytics software that permitted the local processing and analysis of locally collected production-related big data.

In some instances, the local subsidiary proposed certain investments at a multinational company-level brainstorming on the application possibilities of industry 4.0, and the given technological solutions have been adopted.

In other cases the parent company standardised and unified its production system within the global network, and in doing so, the best practices were implemented by each manufacturing subsidiary.

All in all, however, the managers interviewed did not see a causal link between the adoption of industry 4.0 technologies and subsidiary upgrading. At most, as some have mentioned, openness towards the implementation of the new technological solutions gives an opportunity for the Hungarian subsidiary to pioneer the introduction of these applications and to become the 'pilot project' and the 'best practice' that is adopted later elsewhere.

Following the presentation of the results of the interviews, we now return to the questions raised in the introduction, about the impact of industry 4.0 technologies on the value chain position of production in general, and on the upgrading of the surveyed manufacturing subsidiaries, in particular.

Discussion and conclusions

The rapid adoption and intensive use of industry 4.0 technologies, at least in a well-delineated segment of the Hungarian corporate ecosystem, is only seemingly surprising. The surveyed cases of technology diffusion and use are not intended to suggest that the theory of appropriate technology selection needs to be refuted as outdated. Neither do they suggest that the current factor endowments and factor proportions would generally necessitate frontier technology in Hungary.

Instead, the surveyed cases rather serve as an illustration to a new phenomenon, described by *Baldwin* [2014] and by *Whittaker et al.* [2010]. Once integrated in global value chains through foreign direct investment, economic actors do not need to go through all stages of organic development, i.e. of capital and knowledge accumulation. The fast lane of foreign direct investments can make them leapfrog to the technological frontier, at least in terms of production capabilities.

A related argument is provided in *Kravtsova–Radosevic* [2012]. These authors have presented convincing evidence that the spectacular modernisation driven by foreign direct investment has been confined to the production capabilities of economic actors in Central and Eastern Europe. The technological (innovation) capabilities of these actors have, however, hardly improved.

Another issue to be considered when evaluating the results of our research is that these cases represent anecdotal evidence (a couple of pilot projects). The intensive margin of technology adoption is still very low as demonstrated by the poor scores of the Digital Economy & Society Index (DESI, 2016).

Nevertheless, the specific effects of industry 4.0 technologies on the surveyed local subsidiaries only seemingly confirm *Kravtsova–Radosevic's* [2012] cited argument. Advanced manufacturing technologies have, indeed, uniquely positive effects on adopting actors' production capabilities: the cost efficiency, accuracy and reliability of processes improve, resource utilisation becomes optimised, and companies approach operational excellence.

Still, the arguments of *Tassey* [2014] are also confirmed, namely that in the industry 4.0 era production capabilities and technological capabilities are becoming more strongly integrated than ever. This is demonstrated by the fact that the surveyed subsidiaries are not only users of industry 4.0 technologies, but subsidiary experts participate in the customisation and adaptive development of the given solutions, and also in several partial supplementary development tasks. There is a bigger need for the experiences and the expertise of subsidiary engineers than ever before with respect to the manufacturability of new product design, and/or in the deployment, operation and further development of industry 4.0 technologies, and in the development of the manufacturing processes.

This line of arguments takes us back to the theoretical question raised in the introduction: Can the revolutionary manufacturing technologies change the position of manufacturing within the global value chain? Can it be expected that production will move upwards from the bottom of the smile curve?

The point of departure of our analysis is that due to the specifics of the new technologies, the activities that comprise the value chain have become more strongly integrated than ever. Consequently, production has also become more interwoven with development than previously. The number of development tasks that need to be co-located with production has multiplied, though virtual reality-powered technologies have made engineering support provision possible also from distance sites.

What also needs to be taken into account is that the integration of value chain activities cannot be confined to production: cyber-physical systems integrate the whole value chain (*Kagermann* et al, 2013). Moreover, digital technologies support not only production but also traditional headquarter tasks, such as supply chain management, value chain integration and coordination. Furthermore, these technologies enhance a variety of advanced business functions, such as product and process development, and logistics planning. They simplify and even automate other business functions, such as quality control, maintenance, accounting and order processing.

These arguments are strongly related to the reasoning about the competing definitions of industry 4.0 presented in the introductory section. They substantiate the ‘business model perspective’ of industry 4.0, namely that industry 4.0 should not be restricted to technological novelties in manufacturing: it is rather about the competitive advantage gained from the digital transformation of business as a whole.

These arguments make us advance the proposition that it is not the importance (the value chain position) of production that will be altered by the new manufacturing technologies. Individual business functions will seemingly move in the opposite direction along the smile curve: more and more knowledge-intensive support activities will be pushed to the bottom.

Altogether, the positions of individual business functions will become more uniform: the smile will rather take the shape of a bathtub (see figure 1*a* and 1*b*). At the bottom it will be wide and flat, at the sides shorter and steeper. The changed shape of the curve represents that

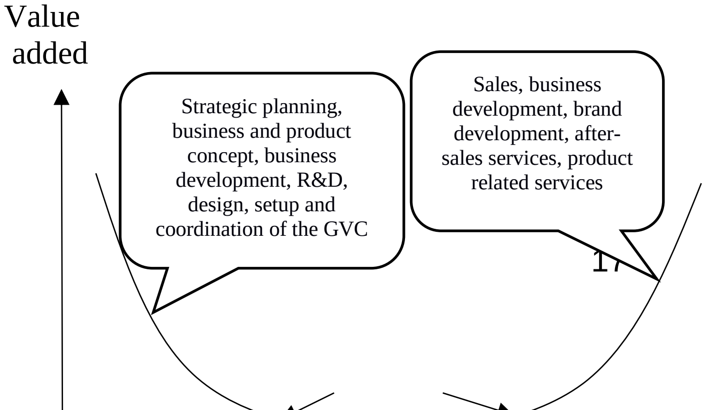
– more and more activities supporting production have become standard inputs that can be procured anywhere (Davenport, 2005);

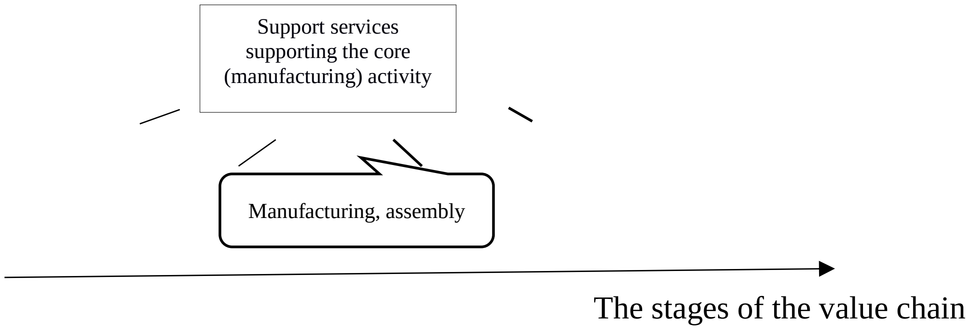
– production has become tightly integrated with the related knowledge-intensive support activities, hence its value added increased;

– the scope of strategic activities that determine companies’ *ownership-specific advantages* (Dunning, 1993) decreased.

Figure 1a

The original smile curve

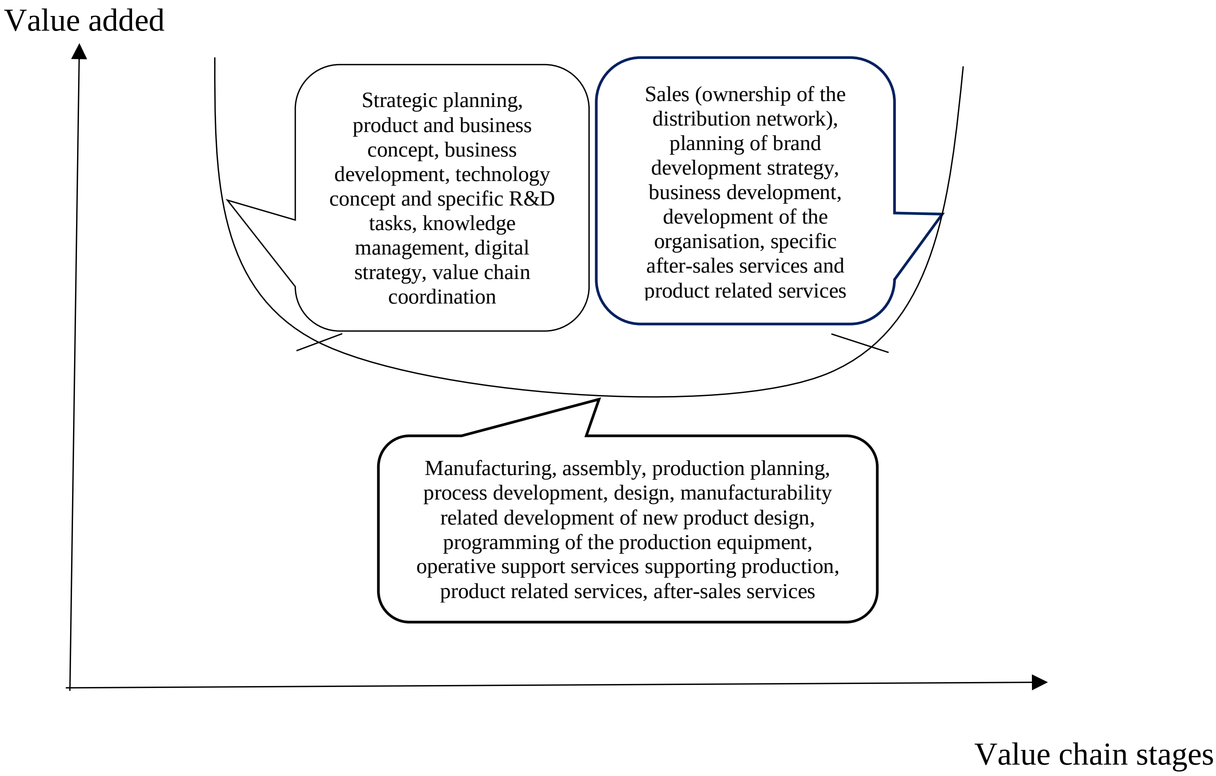




Source: Based on *Mudambi* [2008] with own supplements.

Figure 1b

Industry 4.0-triggered transformation of the smile curve



Source: Author's editing

Finally, some limitations of our research needs to be mentioned. The first one is the modest size of the sample consisting of highly special companies, i.e. hard-to-generalise – though insightful – cases. The second is the shortness of the analysed period of time. Additional research, the increase of the number of surveyed companies and industries, and international comparisons will be needed to establish

- the balance of the skill-biased and skill destroying effects of new technologies;

- the direction and the balance of the geographical reconfiguration of value adding activities
- the impact of new manufacturing technologies on the specialisation, task portfolio and mandates of manufacturing subsidiaries.

Increased and more diversified corporate samples and longer time periods will be needed to convincingly conclude that

– global companies' implementation of industry 4.0 technologies targets existing local manufacturing subsidiaries: instead of reshoring production and the related support activities to advanced economies, existing offshore production capacities are upgraded;

– the labour force (at least the white-collar employees) that becomes redundant as a consequence of production automation and robotisation will be absorbed by the newly created tasks;

– industry 4.0 technologies will increase the number of value chain activities that are considered 'operative' and, conversely, value chain coordinators consider fewer activities really strategic;

– industry 4.0 technologies will reduce the differences in the value chain position (or rather, in the position along the smile curve) of the individual operative activities.

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