Andrea Szalavetz[[1]](#footnote-1)

**Robotics, digitalization, workplace automation: What future for manufacturing in Hungary?[[2]](#footnote-2)**

1. **Introduction**

Although the disruptive technologies of the umbrella term of ‘industry 4.0’ (Brettel et al., 2014; Hermann et al., 2015; Kagermann et al., 2013; Váncza et al., 2011) have been nearly universally hailed[[3]](#footnote-3) as ones bound to improve the competitiveness of manufacturing through multiple channels – also in high-wage countries, scholars are far from unanimous in their assessment of the impact of these technologies on selected specific economic subsystems. The main sphere of controversy is the impact of industry 4.0 technologies on employment and on the labour market. Moreover, the outcome of the coming geographical reconfiguration of value adding activities is also heavily debated.

As for the former issue, some scholars discussed the broad implications of the digital economy, for example, whether the proliferating new forms of employment are expected to call even the social model of paid employment into question (Valenduc and Vendramin, 2016), or, whether by causing massive job losses, new technologies jeopardise overall welfare (Sachs et al., 2015). In a more definite approach, several papers quantified the number of jobs bound to be eliminated by industrial automation and by other industry 4.0 technologies (e.g. Arntz et al., 2016; Bonin et al., 2015; Frey and Osborne, 2013; WEF, 2015), and discussed the implications of these developments on wages, share of labour in national income and inequality (reviewed by Acemoglu and Restrepo, 2016). The results of the calculations were debated by other scholars, claiming that the new technologies will not eliminate jobs in the magnitude posited by some papers. By taking the dullest and the most difficult routine activities over – this second group of scholars claim – new technologies require major adjustment in the labour supply: they eliminate selected activities, but, at the same time, increase demand for new, complex skills, and thus, they enhance the creation of ‘good jobs’ (Acemoglu and Restrepo, 2016; Autor, 2015; Chui et al., 2015; Porter and Heppelmann, 2014).

The second issue, the outcome of the geographical reconfiguration of production activities triggered by the disrupting impact of new manufacturing technologies on global value chains, has raised similar controversies. Whether or not the new manufacturing technologies will bring about major changes in global supply chains, for example, whether industrial automation prompts the massive reshoring to high-wage countries of the previously offshored production activities (surveyed by Oldenski, 2015), or, conversely, whether the co-location synergies that characterise the modern production systems will bring about further relocations (this time, the relocation of advanced activities) to MNCs’ offshore, low-cost manufacturing premises (Tassey, 2014), or whether some industry 4.0 technologies will bring about a further decentralisation of manufacturing (Gress and Kalafsky, 2015) remain to be substantiated by empirical evidence.

This paper is intended to contribute to these strands of the literature from the perspective of FDI-hosting, intermediate-level ‘factory economies’.

Central and Eastern European (CEE) countries, more specifically, Hungary are used as examples of this country group. Following their shift from command to market economy, CEE economic actors have become successfully integrated in European and global value chains (GVC), mainly as subsidiaries of multinational companies. They exemplify the concept of ‘factory economy’ in Baldwin and Lopez-Gonzalez’s (2015) categorisation,[[4]](#footnote-4) even if local economic actors have achieved substantial product, process and functional upgrading.

Investigating the development perspectives of CEE manufacturing actors in an industry 4.0 era is intriguing, since this country group represents an intermediate case. On one hand it is relatively more developed than the peripheral low-cost locations, and on the other hand it hosts manufacturing subsidiaries that have undergone substantial upgrading in multiple respects.

Our point of departure is that the contradictions in the above-detailed assumptions can be reconciled if the focus of the investigations is broadened to include factory economies. Indeed, the impact of industry 4.0 technologies will be function of economies’ GVC-specialisation[[5]](#footnote-5) and of the speed of their adjustment to new skill requirements. If examined in a GVC-perspective, optimistic and pessimistic scenarios may happen in parallel: with the benefits accruing to advanced economies (optimistic scenario), and the costs (the adverse effects of the new technologies) concentrating in peripheral ‘factory’ or dependent market economies (Farkas, 2011; Nölke and Vliegenthart 2009), that are unable to adapt to today’s high-velocity business environment.

The issue at stake is whether or not the new technologies will annul local subsidiaries’ past upgrading achievements. Will the relatively advanced activities that had been located to these countries, partly in recognition of their demonstrated competencies, be reshored?

This issue will be discussed conceptually, drawing on the features of industry 4.0 technologies (section 3). Conceptual analysis draws on a survey of technology and engineering literature to get understanding of the specific attributes of individual technologies. In a multidisciplinary approach, technological and engineering literature is combined with business and management literature to develop predictions about the impact of new manufacturing technologies on changes in the location patterns of selected manufacturing activities – from the particular perspective of intermediate-level factory economies. Manufacturing activities are considered in broad sense (Bernard et al., 2016) including all related business support activities, such as process development and production scheduling; capacity planning; engineering support to assembly line reconfiguration; testing; order processing; accounting, etc.

Conceptual analysis will be complemented with a summary of interview findings carried out to gather information on the adoption of industry 4.0 technologies at MNCs’ manufacturing subsidiaries in Hungary (section 4). These sections will be preceded by a short summary of the literature related to our investigations (section 2). The final section provides some concluding remarks (section 5).

1. **Definitions and related literature**

In a broad sense, industry 4.0 refers to a bundle of technologies[[6]](#footnote-6) that recently penetrated into manufacturing and in the related support activities (often referred to as advanced manufacturing – Tassey, 2014). More narrowly defined, industry 4.0 refers to the implementation of cyber-physical systems, resulting in the digitalisation of the production system (Kagermann et al., 2013; Monostori, 2015). The flipside of the coin is the integration of new technologies in the products themselves: smart connected products, such as autonomous cars, smart apparel, smart consumer electronics products, and smart buildings are cyber-physical systems themselves.

New technologies have dramatically improved adopting firms’ operations parameters, such as efficiency, productivity, transparency, costs, and flexibility. Moreover, they have altered industry boundaries; induced new business models (changed the way how value is created and captured), and have transformed several components of corporate strategy (Porter and Heppelmann, 2014, 2015).

Among the multiplicity of related strands in the literature (e.g. the expected benefits and challenges of the digital transformation; the speed and scope of technology diffusion and factors impacting technology adoption; technical change and industry dynamics; tertiarization of manufacturing and the interdependence between manufacturing and business services; technical change, skills and the labour market; global value chains and upgrading) the closest to our investigation are papers concerned with multinational subsidiary evolution, and with the dynamics of the location of value adding activities along GVCs. These two streams will shortly be reviewed below.

Birkinshaw (1996) and Birkinshaw and Hood (1998) are among the classical references of subsidiary evolution. They posit that over time, subsidiaries systematically accumulate resources and specialised capabilities, which may result in the enhancement of their mandates. Subsidiary evolution is driven by the headquarters’ (HQ) increased expectations and assignments, and by the related transfer of additional resources (moderated by subsidiaries’ absorption capability), and/or by subsidiaries’ proactive behaviour and initiative-taking. The development of unique, subsidiary-specific capabilities (Rugman and Verbeke, 2001) allows them to turn from the status of a peripheral implementer, into one of a strategic contributor (Bartlett and Ghoshal, 1986), or even, into a centre of excellence within their MNC-owner’s network (Frost et al., 2002). Nevertheless, subsidiary evolution is not a one-way street, as argued by Dörrenbächer and Gammelgaard (2010): subsidiary charters can also be lost, driven by technological or host market changes, changes in the overall business environment, or by parent companies’ other strategic considerations.

As for the geographical configuration and the dynamic reconfiguration of value adding activities, there seems to be a consensus in the literature (e.g. Contractor et al, 2010; Koza et al., 2011; Linares-Navarro et al., 2014) that increasingly fine-sliced activities are *assembled* in GVCs. The term ‘assembly’ is used here in Koza et al.’s (2011) conceptualisation of *strategic assembly* (rather than product assembly), defined as a process consisting of (a) the identification of the necessary resources; (b) the design of the value chain structure and access to resources; and (c) the management and coordination of network relationships that include both equity and non-equity relations.[[7]](#footnote-7)

A further common finding is that the attributes and the composition of value chain activities keep changing, driven either by technological and business model innovations (Cano-Kollman et al., 2016), or by HQ efforts to adapt the organisational structure to changes in the external business environment (Chandler, 1962; Szalavetz, 2016).

Location choices are determined by the fit between the nature of the given activity and the tangible and intangible resource endowments of the selected locations. Both components (the attributes of the activities and the endowments of the offshoring/outsourcing destinations) need to be analysed in a detailed manner, to allow for phenomena, where high-cost locations are selected or retained, to host certain manufacturing activities (Jensen and Pedersen, 2011). Moreover, location-based competitive advantages are not static, firms and locations co-evolve with one another (see the review of the related literature in Cano-Kollmann et al., 2016).

This paper attempts to bring these two reviewed streams of the literature together by investigating the implications of industry 4.0 technologies on manufacturing-FDI hosting economies that had already achieved substantial upgrading by the advent of these technologies. We argue that, in line with the evolutionary view (Nelson and Winter, 1982), technological change triggers *selection*, *retention* and *reconfiguration* mechanisms – also within global value chains. In our case, the new manufacturing technologies prompt GVC orchestrators to make strategic locational decisions: whether they (a) keep their existing manufacturing facilities and upgrade them through installing industry 4.0 technologies (retention); (b) consolidate and concentrate manufacturing activities in a (couple of) specific location(s) (selection); or (c) reshore part of the activities, establish new facilities, and/or outsource certain tasks (reconfiguration).

Scenario building from the perspective of specific GVC actors is coupled with uncertainties, not only because these three mechanisms usually overlap at a GVC-level, but also because industry 4.0 technologies are heterogeneous. The impact of individual technologies differs across industries. Even within individual value chains, different industry 4.0 technologies may trigger different geographical reconfiguration mechanisms. The ambition of this paper is thus limited to discussing certain possible developments associated with selected industry 4.0 technologies, from the perspective of MNCs’ manufacturing subsidiaries in Hungary, operating in the automotive and electronics industries.

1. **Industry 4.0 technologies and the geographical reconfiguration of value chains – Impact on MNCs’ manufacturing subsidiaries**

One of the salient technological novelties of the industry 4.0 era is additive manufacturing, referred to also as 3D printing.[[8]](#footnote-8) As the characteristics, the benefits and the disruptive implications of this technology on international business are discussed extensively (e.g. Berman, 2012; Ford, 2014; Garrett, 2014; Petrick and Simpson, 2013), here we call attention only to a couple of thought-provoking specifics – from a factory economy perspective.

Although additive manufacturing is expected to fundamentally reorganise not only the way products are manufactured but also the location patterns of manufacturing activities, its diffusion is projected to be limited to particular product families. The main obstacles to intensive diffusion[[9]](#footnote-9) are the higher costs and the lower production throughput of 3D printing compared to those of conventional manufacturing technologies. Hence, even in the medium-term, it is projected to be used mostly for manufacturing customised products that have a complex design and are made in small quantities (Ford, 2014). Notice that this is the particular area, where factory economies of an intermediate wage level, e.g. CEE, have comparative advantages (Artner, 2005), as FDI inflows in CEE manufacturing have enhanced specialisation in relatively skill-intensive manufacturing (Damijan et al., 2015; Dulleck et al., 2005; Pavlínek et al., 2009).

It is fair to presume that the comparative advantages of CEE as a production location may vanish (at least in these specific products and industries) because of the following reasons. 3D printing technology makes it much easier to change the location of production. Location choice is expected to be determined by the size and the evolution of local market demand, rather than by the skills and the costs of local labour (Berman, 2012; Oettmeier and Hofmann, 2016). Production will move close to customers. Altogether, the location of manufacturing activities that turn to employ 3D printing instead of conventional fabrication methods (e.g. in certain machinery or automotive component industries) may easily be transferred close to final or intermediate customers[[10]](#footnote-10) – away from the current middle-wage level countries.

Another oft-mentioned benefit of 3D printing is that it eliminates one expensive and time-consuming step of new product launch: tooling (e.g. Rosochowski and Matuszak, 2000).[[11]](#footnote-11) Moreover, in hybrid processes, 3D printing can be applied to prepare the tools themselves, which, once ‘printed’, can be used in conventional manufacturing processes (Holmström et al., 2016; Oettmeier and Hofman, 2016). Again, tooling is a GVC task, where CEE actors have comparative advantages. Corporate interviews (e.g. Sass and Szalavetz, 2013; 2014) indicate that functional upgrading in manufacturing subsidiaries was manifested, among others, in their taking up the responsibility for tooling – above and beyond their core production activities. It remains to be seen whether 3D technology triggers a reshoring of tool design to advanced economies.

A further IT-enabled industrial solution of the industry 4.0 era is virtual reality-powered product and process development, and the virtual provision of engineering support to various manufacturing related processes in distributed industrial locations.

Factory economies will be confronted with a thought-provoking implication of this evolution in ways of connecting, knowledge sharing and collaboration.[[12]](#footnote-12) Several scholars subscribe to the argument that the geographical separation of tasks that compose a value chain is not without limits. Keeping tasks together produces economies of scope (e.g. Lanz et al., 2011; Larsen et al., 2011). Ketokivi and Ali-Yrkkö (2009, p. 35) argue that “as knowledge-intensity of economic activity increases, the unbundling of several functional activities may no longer be possible: R&D, innovation, design, and branding may be activities that are intimately related with the manufacture of physical products.” Tassey (2014) maintains that certain manufacturing-related advanced support activities display non-negligible co-location synergy. For example, in the case of new product launch related development activities, where technical knowledge is not standardised yet and requires continuous adjustment, person-to-person interactions are critical, since tacit knowledge is transferred. Tassey argues that in the industry 4.0 era, characterised by technological transition in multiple fields of the manufacturing process, co-location synergies will facilitate manufacturing locations’ capturing responsibility for and critical competences in advanced support activities, which will ultimately result in advanced economies’ loss of competitiveness.

However, the cited authors fail to calculate with advanced virtual-reality and augmented-reality technologies that allow for sustaining the geographical separation of tasks and for the remote provision of process planning and process engineering support to manufacturing facilities: bad news for manufacturing locations wishing to move up the value chain!

From the perspective of intermediate-development-level factory economies, the implications of some other industry 4.0 technological solutions may represent a threat not only to future upgrading opportunities (in the field of manufacturing related process development), but may also jeopardise prior upgrading achievements. Most of the smart computing solutions embedded in cyber-physical production systems digitalise activities – and thus, perform them themselves – that used to be classified as upgraded actors’ knowledge-intensive assignments. Examples of knowledge-intensive, relatively high-value-adding activities, mentioned during the author’s prior interviews (Sass and Szalavetz, 2013; Szalavetz, 2015) were layout (and factory) planning, process configuration, production planning and scheduling, investigation of the machinability of new product design, process development, e.g. reduction of changeover time, reduction of throughput time. Augmented reality-powered digital factory applications (Pentenrieder et al., 2007) are expected to redefine the tasks of local engineers engaged in layout and factory planning. Advanced computing solutions, such as (a) big data–enabled predictive maintenance (Lee et al., 2013); (b) modelling and simulation-based smart algorithms for production planning and scheduling, and capacity control, etc. (e.g. Gyulai et al., 2015); (c) modelling and simulation-based smart algorithms for process optimisation and improvement of capacity utilisation, throughput and overall effectiveness (e.g. Bard et al., 2015) are bound to take over production planning, scheduling and process development tasks, carried out currently by local engineers. At least, they are bound to redefine the task portfolio of local engineers and the skill requirements of their jobs. Altogether, advanced computing solutions may put local manufacturing subsidiaries’ past functional upgrading results in jeopardy.

Furthermore, artificial intelligence and deep learning solutions will automate selected medium knowledge-intensive support activities (routine cognitive tasks) such as accounting, order processing, payroll management, operational procurement (Lacity and Wilcocks, 2015). This jeopardises CEE actors’ functional upgrading achievements, manifested in the location of shared services centres – near MNCs’ manufacturing subsidiaries (cf. Sass and Fifekova, 2011). With the automation of these tasks a large number of jobs may disappear.[[13]](#footnote-13)

Conversely, selected properties of industry 4.0 technologies represent upgrading opportunities for factory economies.

One is their compatibility with legacy systems. New technologies can be deployed step-wise: advanced robotic and/or 3D printing solutions, sensors and various devices can be added to the existing production systems without jeopardising their functionality (Colombo et al., 2014). Since scalability, modularity and interoperability are important attributes of cyber-physical systems, this allows for a progressive reconfiguration of the architecture of existing production systems. Existing production facilities can thus be transformed into ‘factories of the future’ in a gradual manner. Compatibility with legacy production systems is expected to prompt parent companies to upgrade their existing manufacturing assets in factory economies, instead of establishing brand new ‘industry 4.0’-facilities in their home countries.

A further opportunity is that the operation and maintenance of the advanced manufacturing solutions that were so far deployed to factory economies, required substantial development of subsidiary-level engineering capabilities. Selected activities that had been delegated to upgraded local manufacturing subsidiaries may have non-negligible multiplier effects, prompting parent companies’ delegation of further knowledge-intensive assignments. They include the programming of industrial robots, or subsidiary-level R&D undertakings aiming at process development through experimental analysis, measurement and testing, modelling and simulation of manufacturing processes.

1. **Experience with industry 4.0 at MNCs’ manufacturing subsidiaries in Hungary – Sample and interview results**

Applying a purposeful sampling method (Patton, 1990) with the aim of selecting information-rich cases, i.e. companies whose cases promise insightful observations about issues related to our research, we selected eight companies to make in-depth interviews with. Furthermore, two interviews were carried out with representatives of a Hungarian research institution, specialised in industry 4.0 related software solutions.

The sample of manufacturing companies consists of eight large,[[14]](#footnote-14) foreign-owned technology users in the automotive and electronics industries. Note that two of them can be classified, at the same time, as technology producers: they are specialised in the manufacture of intelligent sensors, and data acquisition related hardware and software, programmable automation controllers and automated test systems.

We selected MNC subsidiaries because they are the forerunners of new technology implementation. Note that according to the European Commission’s Digital Economy and Society Index (DESI, 2016) Hungary ranks 20th out of the 28 EU Member States, and it is lagging behind, in particular, in terms of the integration of digital technology by businesses.

An interview guide containing predominantly open-ended questions allowed interviewees to provide a detailed description of their experiences with the new technologies. We first inquired about the awareness of the management of industry 4.0 trends and technologies. We also wanted to find out, whether a systematic digital strategy was behind new technology implementation at the Hungarian facilities, and further investments – aligned with a more or less predetermined roadmap – are expected. Next, we asked about the purpose of these investments (cost cutting versus quality and efficiency improvement).

The interviews, 45 to 60 minutes in length, were conducted between April and July 2016. Interviewed managers were the chief executive officers, division leaders or chief technology officers of the Hungarian subsidiaries. To preserve anonymity, neither corporate names nor main products will be specified.

***Awareness and implementation of industry 4.0 technologies***

The first finding that crystallised during the interviews is the surveyed organisations’ relatively high degree of preparedness for and adoption of industry 4.0 technologies. The managers interviewed were not only aware of the new technological trends labelled with the umbrella term of industry 4.0, but local subsidiaries had already implemented significant investments in the new technologies.

Above and beyond the two specialised technology producers, some of the surveyed technology users turned out to be, at the same time, also technology producers. On one hand, the measurement and testing equipment applied in the production process is developed by several companies in-house. On the other hand, cyber-physical production systems are not off-the-shelf solutions. They cannot be fully specified at the time of their design, and they usually need to be extended and adapted over the course of their deployment, and quasi continuously modified during operation. Consequently, the IT staff of manufacturing companies takes due part in the customisation, integration into factory operations and in the subsequent adaptations of the purchased solutions (reprogramming).

The interviews indicated that the adoption of industry 4.0 solutions is not a ‘yes or no’ issue: it is rather a gradual evolutionary journey encompassing a multitude of advanced techniques. Indeed, at several companies the implementation of industrial automation solutions, or the use of sensors and the incorporation of traceability solutions in the manufacturing processes started more than a decade ago. Networked equipment, controlled by computing algorithms have also been part of the production systems of selected firms, for at least a decade. The main novelties, the executives interviewed mentioned, can be identified in three respects. First, in terms of advanced data acquisition with respect to a wide variety of production parameters, to be analysed with advanced data mining techniques. The second, related novelty is the unprecedented transparency of the whole production process. The third novelty is man–machine collaboration (robots are no longer behind fences). Nevertheless, the current hype about industry 4.0, as one of the managers interviewed explained, is not because of the alleged *revolutionary* character of the technologies, rather because of their better visibility. The costs of advanced solutions have declined below a threshold level, which triggered a virtuous circle in terms of the diffusion, the costs and the quality improvement of the individual solutions.

Nevertheless, there is a long way to go from adopting basic industry 4.0 applications to becoming a fully integrated business unit, where communicating and collaborating devices are networked and integrated in MNC-wide installations, and where computational algorithms autonomously monitor, control and manage (intervene into) the manufacturing system – including manufacturing related support processes.

The production systems of several of the surveyed technology users[[15]](#footnote-15) can be labelled as showcase of ‘factory of the future’ (though a strong selection bias applies). They are not only characterised by a high level of automation – especially with respect to high-precision, high-accuracy, physically difficult, high-volume, repetitive tasks, but are also equipped with cyber-physical systems with embedded sensing, measurement, and data extraction solutions. Some companies apply advanced decision support systems, and rely on 3D visualisation of manufacturing, assembly and related shop-floor logistics processes (virtual factory).

One explanation of the relatively high level of industry 4.0 technology adoption – at least among the flagship companies surveyed[[16]](#footnote-16) – is Hungary’s status of an FDI-driven ‘factory economy’. On one hand, flagship MNCs apply global corporate standards, including standardised systems architecture, standardised technology modules and standardised work practices – obviously, also at their manufacturing subsidiaries.[[17]](#footnote-17) Moreover, industry standards prescribing increased product traceability also account for the rapid diffusion of the new manufacturing and testing technologies.

On the other hand, digitalising the shop-floor and making factories smart is by orders of magnitude easier and quicker than implementing ‘headquarter economy’-type tasks related to digital transformation (DT). DT in factory economies involves the application of digital tools and methods that automate, enhance and optimise the existing way of working. Conversely, in headquarter economies, DT refers to new ways of working, to a fundamental transformation of the rules of the game, e.g. transition to platform competition; entry in new industries; business model innovation; innovative digital services provision and product differentiation based on a big-data/business analytics-based thorough knowledge of customers (cf. Porter and Heppelmann, 2014). The main purpose of digitalisation in headquarter economies is flexibility and responsiveness, through creation, management and implementation of *new processes*. Conversely, in factory economies, the main purpose of technology adoption is the operational excellence of the *existing processes* (see below). Consequently, DT in factory economies – at least in their FDI-driven segments – is much more rapid than in headquarter economies.

***Purpose of technology adoption***

Another finding of the interviews was that (except for a few cases) even the advanced local users of industry 4.0 applications lack a systematic digital strategy. Going after particular outcomes, they invest in selected advanced solutions. However, the investment actions of few companies are aligned with an elaborated roadmap of digital transformation.

The primary purpose of investments was the solution of specific challenges. The challenges mentioned during the interviews fall into four categories:

1) Shop-floor technological problems.

Examples of shop-floor technological problems included inefficient process scheduling, excessive downtime, long changeover time, earlier-than-expected tool wear, product defects, low overall equipment effectiveness, variation of cycle time because of poor process stability etc.

2) Shortage of skilled labour.

Labour shortage (with respect to both operators and engineers), was one of the most commonly mentioned challenges. Together with the falling costs of industrial robots, this was an important driver of some of the surveyed firms’ adoption of industrial automation solutions.[[18]](#footnote-18)

3) Increased complexity of production activities.

The solution to this problem was the implementation of advanced production planning and production scheduling systems, integrated with the core enterprise resource planning (ERP) system.

4) Increased customer requirements in terms of time, variety, costs, and flexibility.

Above and beyond addressing operational challenges, the surveyed companies’ quest for a general improvement both in productivity and operational excellence was also uniformly stressed as a key motivation of investments in industry 4.0 technologies.[[19]](#footnote-19) Examples include the deployment of a visual recognition system combined with machine learning for quality inspection (to identify anomalies). Furthermore, seeking to prevent problems that may emerge during the production process and to minimise maintenance associated costs, industry 4.0 solutions (e.g. computerised maintenance management systems, relying on big data analytics or on simulation-based smart algorithms) have been applied to predict and control problems that may emerge within the production system.

Although the reduction of costs was not among the explicitly stated purposes, this factor was also mentioned among the expected benefits of technology adoption. The purpose of cost reduction came up indirectly, in the form of the expected rapid return on investments in industrial robots that, indeed, triggered a reduction in the number of operators.

Nevertheless, efficiency increase (reduction of machine downtime, and of interim storage; a close-to-optimal allocation of work assignments and efficient use of other resources, such as material and energy) was apparently a more important objective of investments in smart systems than a mere reduction of costs.

***Impact on jobs***

The interviews made it clear that new relatively low-cost robots have indeed reduced demand for operator jobs at the surveyed companies. Nevertheless, as emphasised by the executives interviewed, the impact of the new technological solutions on jobs is not straightforward, it needs a nuanced assessment. On one hand, these robots represent a solution to labour shortage. On the other hand, the reduction of demand for operators related to specific activities has not resulted in overall job losses. It was rather manifested in relative terms, in terms of the labour content per unit of output. Over the surveyed period, between 2012 and 2015, sample companies have undergone considerable production expansion, which necessitated the expansion of the workforce.[[20]](#footnote-20) Hence, the operators whose tasks had been automated were reallocated to other production activities.

At the same time, the deployment of some smart solutions has taken over some tasks also from white-collar workers. For example, automated data extraction solutions have freed up engineers from preparing daily reports about selected parameters of the production process. The introduction of big data analytics solutions has taken over analytics tasks from engineers who used to spend a couple of hours on a weekly level, studying production data and trying to discover patterns that reveal the root causes of disruptions and other anomalies. Production planning and scheduling software have redefined the jobs of engineers who used to be responsible for these tasks. Quality control has become increasingly automated.

It was mentioned in some cases, that the redefinition of engineers’ tasks and the expectation of engineers’ being able to work supported by smart systems, have sometimes necessitated ‘qualitative changes’ in the white-collar workforce. On the other hand, the engineers that possess adequate technical and non-technical skills are experiencing increasingly intensive *intra-firm competition* for their talent: they keep being tempted to move to (regional or central) HQ premises, and become engaged in more challenging, more knowledge-intensive (and obviously better-paid) activities there. Assessing this phenomenon from a ‘factory economy’ perspective, as some of the executives interviewed did, this may jeopardise subsidiary upgrading perspectives.

A common observation of the managers interviewed was that focusing on new-technology-related relocation of tasks and on job losses is not the right approach of our investigation. In an MNC’s production system, characterised by end-to-end digital integration (along the entire value chain), the question where a particular processing task is carried out is less and less relevant, at least from the headquarters’ perspective. Even internalisation (ownership-based control) has become less relevant than before, due to advanced communication and virtualisation technologies. From the headquarters’ perspective, only *access* to capacities and competencies and the end-to-end *control* of the processes are important. Of course, from the perspective of local subsidiaries the pursuit of an ‘entrepreneurial’ subsidiary strategy (Birkinshaw and Hood, 1998) is of crucial importance in order to withstand the intensified selection mechanisms triggered by technological change. Aiming to maintain or improve subsidiary position, Hungarian subsidiaries strive to spearhead new technology implementation. Several executives interviewed remarked that pioneer adopters within the MNC’s organisation may turn into ‘industry 4.0 competence centres’, and thus, local experts may become responsible for best practice transfer to partner subsidiaries.

As for the impact of new technologies on jobs, the executives interviewed maintained that this research focus is irrelevant for companies trying to withstand global competition. New technology implementation is simply a must: competitiveness will otherwise soon erode, and markets will be lost. The imperative of operational excellence requires the deployment of robotic solutions, for example, to achieve high-accuracy machining and welding. As big data and simulation-based computing applications addressing multiple aspects of operational excellence are proliferating, technology-push factors are equally important determinants of the adoption of new solutions as demand-pull ones.

1. **Conclusion and policy implications**

Based on an overview of the literature about the attributes and the expected impacts of industry 4.0 technologies, this paper developed a rather pessimistic scenario, from the perspective of ‘factory economies’ in general and CEE in particular. In this scenario, economies of an intermediate development level are bound to be hit hard by the new manufacturing technologies. These technologies will provoke massive job losses which will not be compensated for by the creation of new skill-intensive jobs – not because local demand for ‘good jobs’ will not increase, rather, because in the ‘second machine age’ (Brynjolfsson and McAffee, 2014), the education system of these countries, and in particular that of Hungary, is bound to fall behind in ‘the race between education and technology’ (Goldin and Katz, 2008).

It was also predicted that part of the relatively advanced assignments, gained by upgraded local actors might be lost: reshored, relocated or automated. Consequently, selected past upgrading achievements might be repealed.

Empirical evidence has however only partly supported these pessimistic predictions. Interview findings suggest that instead of relocating / reshoring production, MNC owners tend to upgrade their existing production facilities, by implementing industry 4.0 solutions. This is made possible by the attribute of these technologies that they are (or can be made) compatible with legacy production systems and legacy technologies.

Note that the implementation of advanced manufacturing technologies (local subsidiaries’ technology upgrading) is only seemingly confined to improvement of the given actors’ *production capability*. With the advent of the fourth industrial revolution, technological capability and production capability have become more strongly interwoven than ever (Tassey, 2014), and the deployment of new technological solutions requires subsidiaries’ non-negligible in-house technology efforts. As the experience of some of the surveyed companies illustrates, demonstrated capabilities during the deployment of industry 4.0 technologies opened up additional opportunities for subsidiary engineers to participate in MNC-wide technology development activities. Consequently, it is fair to claim that *with the advent of industry 4.0, the disjunction between technology use and technology generation that used to characterise the transformation and integration decades of CEE[[21]](#footnote-21) has become less tenacious than before.*

Interviews also indicated that the newly implemented solutions have indeed led to reduced demand for operators in the given activities. It is anticipated that this tendency will continue. At the same time, production expansion increased the surveyed firms’ overall demand, both in terms of skilled operators and of highly skilled engineers, who have a deep understanding of the production system (how individual parts of the systems are related to each other and to the system as a whole), and understand the tools and techniques of testing and maintaining the production system. This made the labour shortage local subsidiaries have been facing already for some time, even more pressing than before.

The main policy implication of the results is that immediate action is needed to reform factory economies’ education system. Delays in enhancing the supply of adequately skilled workers and aligning skill formation with demand for skills may eventually hinder the adoption of advanced manufacturing technologies, and will indeed lead to the relocation of activities. As one of the interviewees remarked, “We badly need ‘vocational schools 4.0’, where future workers are educated to use modern technologies, and will possess, at least, some basic programming skills.”

It can be concluded that it is not technological progress in the field of industry 4.0, per se that hits factory economies hard: it is the rigidity of their labour market and of their education system that makes them losers of the digital transformation of manufacturing.

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1. Hungarian Academy of Sciences, Budapest. [↑](#footnote-ref-1)
2. This paper was prepared under the common Polish-Hungarian Project „Development pattern of CEE countries after 2007-2009 crisis, on the example of Poland and Hungary” in the framework of an academic cooperation contract between the Polish Academy of Sciences and the Hungarian Academy of Sciences in 2014-2016. [↑](#footnote-ref-2)
3. Notable exceptions include Benzell et al, 2015; Brynjolffson and McAfee, 2014; Sachs et al., 2015. [↑](#footnote-ref-3)
4. According to Baldwin and Lopez-Gonzalez (2015), in international production networks there are headquarter economies that “arrange the production networks” and factory economies that “provide the labour” (p. 1696). Scrutinising economies’ trade patterns the cited authors found that factory economies tend to be heavily reliant on the closest high-technology manufacturing giant – the US, Germany and Japan – whereas the sourcing and sales partners of headquarter economies are diversified. [↑](#footnote-ref-4)
5. For example, according to the data published in the Economist (2016), half of the world’s full-time call centre jobs are located in two countries: the Philippines (26%) and India (24%). As most of these activities will be subject to the automation of knowledge work – at least of routine cognitive activities (Manyika et al., 2013) the performance indicators (output, export, employment) of these countries will be hit by the new technologies more than the average. In a similar vein, countries specialising in low-skill repetitive manufacturing activities will also face dramatic job losses: for example, in May, 2016 Foxconn fired 60,000 workers in China, as their activities were automated (Millward, 2016). [↑](#footnote-ref-5)
6. Examples of new technologies include cyber-physical production systems and the Internet of Things; big data; artificial intelligence and machine learning; cloud computing; 3D printing (additive manufacturing); industrial robots, and optical 3D measurement (Manyika et al., 2013; Monostori, 2015). [↑](#footnote-ref-6)
7. The business units where the individual value adding activities take place are not necessarily in the ownership of the value chain orchestrator. As Koza et al. (2011) formulate: ownership of resources property rights, assets and operational capabilities is not necessary for competitive advantage. Ownership may even limit firms’ flexibility: their capability to adapt to changes in the business environment. [↑](#footnote-ref-7)
8. Ford (2014, p. 2) clarifies the term 3D printing as follows. „Unlike traditional manufacturing processes involving subtraction (e.g., cutting and shearing) and forming (e.g., stamping, bending, and moulding), additive manufacturing joins materials together to build products” by depositing successive layers of polymers, ceramics, or metals. The creation of physical products relies on digital models and is computer-controlled, hence it is also referred to as direct digital manufacturing. [↑](#footnote-ref-8)
9. Intensive diffusion refers here, to the range of products manufactured using 3D printing (while extensive diffusion refers to the variety of geographical locations where 3D printing technology is applied). It is argued that in contrast to rapid extensive diffusion, intensive diffusion will depend on the further development of the technology. [↑](#footnote-ref-9)
10. By intermediate customers we refer to the production locations where the components and subsystems are assembled into a final product. [↑](#footnote-ref-10)
11. Note that originally, 3D printing was applied only in rapid prototyping. In that case, acceleration of product development was made possible among others by this feature of the technology: the procedure of design and manufacture of prototype tools was eliminated. This attribute of additive manufacturing is reflected by the third terminology in use, as a synonym: direct digital manufacturing. [↑](#footnote-ref-11)
12. Advanced visualisation solutions (e.g. the virtual representation of robots, machine tools, work pieces etc.) and advanced interaction (interactive real-time 3D simulation) tools allow for testing production systems or parts thereof before any actual deployment or installation. They make it possible to remotely evaluate and resolve the problems that emerge in the context of industrial processes (Galambos et al., 2015). Concurrent (simultaneous) engineering (reliance on virtual reality) has been an established collaboration method already since the 2000s, and the related enabling technologies (visualisation, object manipulation, interaction) have been incrementally developed ever since. Virtual reality technologies make it possible that experts from various areas (designers, manufacturing planners, process engineers, marketing and procurement specialists, management, etc.) and in distributed physical locations collaborate in joint product (or process) development undertakings. Conversely, augmented reality techniques enhance users’ (e.g. assembly operators’) perception and understanding of the surrounding world are used in system maintenance and assembly operations (Ong and Nee, 2013). [↑](#footnote-ref-12)
13. According to press releases of the Hungarian Outsourcing Association ([www.hoa.hu](http://www.hoa.hu)) both the number of and employment in shared services centres increased spectacularly in Hungary. In 2016 their number reached 90, with total employment above 35,000. [↑](#footnote-ref-13)
14. Sample companies’ (n = 8) average turnover amounted to € 335 million in 2015, and their average employment was 1,281. [↑](#footnote-ref-14)
15. Note that there are some intra-sample disparities in this respect. The surveyed companies have all implemented industrial automation solutions, though there are differences in the degree of industrial automation. Some of them have invested only in standard robotic solutions, others are already experimenting with human–robot collaboration systems. The surveyed companies gather data generated during the production process, but in most cases business analytics is implemented by parent companies – though some subsidiaries recently invested also in business analytics solutions. [↑](#footnote-ref-15)
16. As it was emphasised by the technology producers interviewed, there are large size- and ownership-specific differences with respect to the adoption of industry 4.0 technologies. [↑](#footnote-ref-16)
17. Obviously there are intra-MNC differences with respect to the deployment of specific solutions. For example, the pilot introduction of some new technological solutions usually takes place at manufacturing facilities at the HQ’s location. [↑](#footnote-ref-17)
18. This increasingly pressing problem is not limited to Hungary. According to Sondergaard et al.’s (2012) investigations, the shortage of skilled manual workers emerged as one of the most important constraints ahead of firms’ expansion overall in Central Europe. [↑](#footnote-ref-18)
19. One of the manager interviewed remarked: “With the deployment of the automated optical inspection system and of the production planning and scheduling software, one of our objectives was to achieve a productivity level that corresponds to 95% of the level of our parent company’s production facility in Germany.” [↑](#footnote-ref-19)
20. Over this period, the number of sample companies’ employees increased on the average by 22.6%. [↑](#footnote-ref-20)
21. See Kravtsova and Radosevic (2012) who argued that productivity growth in the CEE region has been based predominantly on improvements in actors’ production capability and not on their enhanced technological or innovation capability. [↑](#footnote-ref-21)