Chapter 3
Digital transformation and local manufacturing subsidiaries in central and eastern Europe: Changing prospects for upgrading?

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1. Introduction

The digital transformation (DT) of value generation is expected to transform the drivers of growth, upgrading and modernisation in 'factory economies'.[1] Advanced robotics, cyber-physical systems and artificial intelligence-powered business process automation are anticipated to bring about unprecedented technological unemployment (Brynjolfsson and McAfee 2014; Frey and Osborne 2017), in particular in countries specialised in activities that are exposed to automation (World Bank 2016). Some pessimistic observers have contended that these technologies may even induce a downgrading process in these countries or jeopardise local subsidiaries' prior upgrading achievements by automating some relatively knowledge-intensive tasks[2] now being performed by local engineers (Flecker and Schönauer 2016; Szalavetz 2017). Moreover, the very reason for maintaining the current pattern of the global division of labour (keeping previously relocated labour-intensive business processes in low-cost countries) might also be questioned since smart factories controlled by a minimum number of staff can be located anywhere, e.g. close to final markets or in investors' home countries (Dachs *et al.* 2017).

However, an opposite scenario is also conceivable in which existing manufacturing units, representing locally-embedded production capabilities, are upgraded by advanced manufacturing technologies. Consequently, FDI-hosting factory economies could undergo further capital deepening, with local manufacturing subsidiaries receiving further investment in tangible and intangible capital. Moreover, DT might support and enhance the decentralisation of increasingly advanced activities within organisations, including engineering, design and software development. This would enable factory economy actors to accumulate technological and R&D capabilities (Szalavetz 2019a) and increase the knowledge intensity of their contribution to total value added. In short, while the first, pessimistic scenario is about factory economy actors' downgrading and the loss of previously-acquired competitive advantage, this latter scenario suggests a DT-driven further modernisation and upgrading of these countries.

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1. According to Baldwin's (2013) categorisation, in international production networks there are headquarter economies, where economic actors mainly govern the production networks (and carry out business development and other intangible activities); and factory economies that provide the labour.

2. Examples include: tooling and design – jeopardised by the diffusion of additive manufacturing solutions; process development – taken over by self-optimisation solutions embedded in cyber-physical production systems; production planning – superseded by smart planning algorithms; maintenance planning – subsumed within embedded predictive maintenance solutions; engineering – taken over by virtual engineering (cf. Will-Zocholl 2016); and other technological support tasks.

This research seeks to contrast these two contradictory hypothetical scenarios with initial empirical evidence drawn from three central and eastern European (CEE) countries: Czechia, Hungary and Poland. Interview-based case study research was conducted at a sample of automotive subsidiaries in these countries to explore the developmental outcomes of DT.

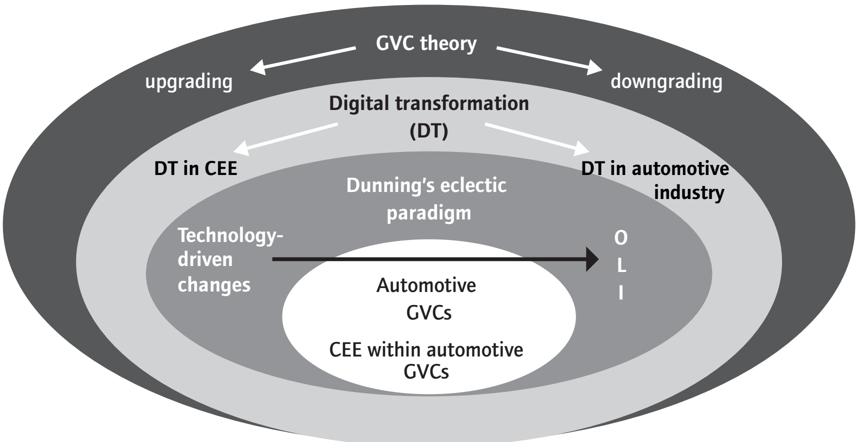
The automotive industry, dominated by foreign-controlled, export-oriented manufacturing units: subsidiaries of global original equipment manufacturers and their global suppliers (Pavlínek 2017), was selected as the specific context for the research since this industry is a forerunner, also in central and eastern Europe, in adopting digital technologies. With nearly continuous large-scale investment inflows, this industry has been one of the main drivers of growth, employment and exports in the 'integrated periphery' of the European automotive industry (Pavlínek 2018).

The rest of the chapter proceeds as follows. First, some related strands in the literature are listed and reviewed (section 2). Research design, data collection and data analysis methods are outlined in section 3, while the results of the data collection exercise are presented in section 4. Section 5 provides a discussion and some concluding remarks.

2. Related literature

There are at least four strands in the literature that are relevant to this research (Figure 1).

Figure 1 **Research related to digital transformation**



Source: elaborated by the author

The first is the scholarship on global value chains (GVC).[3] The GVC method of analysis is constituted from an analytical approach used to investigate changes in (a) the global composition of the value adding activities of geographically dispersed, networked and functionally integrated economic actors; (b) the governance of these activities; and (c) the global distribution of value added (Dicken 2003; Gereffi *et al.* 2005; Gereffi and Fernandez-Stark 2016). It is, in particular, the literature on upgrading – a key construct in the GVC literature – that guides this research. Upgrading is defined as specialising in higher value adding activities within GVCs than previously, achieved by enhancing existing capabilities and/or developing new ones. In Humphrey and Schmitz's (2002) classification, upgrading may refer to (better) products; improved and more efficient processes; higher-skill functions; and/or the shift to new and technologically more advanced sectors or value chains. At the same time, the opposite tendency – the issue of downgrading – may also be relevant (cf. Blažek 2016).

Another stream of research deals with the economic and business implications of digital transformation. Rapid developments in computer science and in information and communications technologies, the emergence of several enabling technologies[4] and smart applications, and the interplay between manufacturing science and computer science and technology (Monostori 2015) have all revolutionised manufacturing operations and business management practices. Digital solutions improve the excellence of operations, enhance productivity, contribute to resource optimisation and allow for faster and more substantiated (data-supported) decision-making (Brettel *et al.* 2014). Note that most scholars maintain that the revolutionary aspect of DT is not limited to manufacturing production. DT is, rather, about an across-the-board transformation of business, implying new business models and new ways of organising, integrating and controlling value adding activities. Consequently, digital transformation is also referred to as the fourth industrial revolution, or Industry 4.0 for short (Kagermann *et al.* 2013; Manyika *et al.* 2013; Schwab 2016).

The studies most closely related to the subject of this chapter take a focused perspective, discussing the specifics of digital transformation in CEE (e.g. Horváth and Szabó 2019; Prašnikar and Redek 2019; Szalavetz 2017) and/or in the automotive industry. These latter contributions are concerned not only with the impact of digital technologies on automotive end-products (vehicles), components, production processes and associated business functions but they also explore digitalisation-driven changes in business models and in the composition of and key actors in GVCs (e.g. Burkacky *et al.* 2019; Ferràs-Hernández *et al.* 2017; Xu 2019).

The third strand of the literature on which this research draws originates in Dunning's eclectic paradigm (Dunning 1993), applied in particular with regard to the question of whether any technology-driven changes can be observed in firms' ownership, location and internalisation advantages (Strange and Zuchella 2017). For example, the issue of

3. GVCs describe the full range of the tangible and intangible activities carried out to bring a product or service from its conception to its end use and beyond (Gereffi and Fernandez-Stark 2016).

4. These include the Internet of Things (IoT), cloud computing, 3D printing, artificial intelligence, big data analytics, virtualisation and augmented reality. Some scholars refer to cyber-physical production systems as the epitome of the digital transformation of manufacturing (e.g. Monostori *et al.* 2016).

offshoring and backshoring in the Industry 4.0 era (Dachs *et al.* 2017) can be discussed within Dunning's framework: in terms of firms' evolving competitive and location strategies (Di Mauro *et al.* 2018) or in terms of the evolution of governance modes in international business networks (Alcácer *et al.* 2016).

Papers in the fourth research strand are concerned with the features of automotive value chains (e.g. Sturgeon *et al.* 2008) and with (any changes in) the position and role of factory economies in CEE within automotive value chains (Pavlínek 2017).

These research strands all convey the message that GVCs are in constant flux, hence they need to be analysed taking an evolutionary approach. GVC dynamics, manifested also in the phenomena of actors' upgrading and downgrading, is driven among others by external factors (e.g. changing business, institutional and regulatory environments), lead firms' adaptation and strategic actions, actors' capability accumulation and, most importantly from the point of view of this research, technological progress. New technologies may transform both the existing organisation of value creation activities and associated power relations. For example, DT is expected to have a transformational impact on various dimensions of GVCs, including firm-specific and locational advantages, geographic scope and governance (Porter and Heppelmann 2014; Rehnberg and Ponte 2018; Strange and Zuchella 2017).

Against this background, we propose that digital technologies have produced an outwards shift in the production possibility frontier. In line with the theory of GVC integration-driven catch up (OECD 2013; UNCTAD 2013), in low-cost locations the local manufacturing subsidiaries of global companies were the first to embrace these technologies. The integration of these technologies in the production systems of local subsidiaries brings about an array of opportunities to increase the efficiency of operations. A pure deployment of new technologies is not sufficient: to exploit these opportunities, local subsidiaries have to develop their technological capabilities and make complementary intangible investments, e.g. transforming their processes and organisational set-up to implement new production methods. Consequently, in addition to learning-by-doing and process upgrading, digital upgrading also engenders functional upgrading. Moreover, upgraded production methods and the related increases in subsidiaries' competences can substantiate product upgrading; that is, assignments to manufacture technologically more sophisticated products than previously. Additionally, since digital transformation increases the complexity and the software-intensity of all value adding processes, this may incentivise parent companies to delegate partial R&D tasks to competent subsidiaries.

Altogether, digital upgrading enables both process and functional upgrading and may also beget product upgrading. Conversely, delays in – or the lack of – digital upgrading are associated with a rapid loss of competitiveness since the distance of companies with unchanged technology to the production possibility frontier thereby increases to such an extent that it makes survival impossible.

3. Research design, data collection and analysis

Since the purpose of this research was to clarify which of the hypothetical scenarios advanced in the literature on the developmental impact of DT is supported by real-world evidence, we decided on an exploratory, qualitative approach, drawing on a field-based data collection method: multiple case study analysis (Eisenhardt 1989; Yin 2014).

We applied the method of purposeful sampling (Patton 1990) and chose companies representing illuminative cases from the point of view of implementing digital manufacturing technologies.

We selected companies that differ in their degree of Industry 4.0 maturity. The literature abounds in measurement models for the maturity of Industry 4.0 (e.g. Mittal *et al.* 2018; Nick *et al.* 2019; Schumacher *et al.* 2016; Schuh *et al.* 2017; Scremin *et al.* 2018). These authors analyse various dimensions of Industry 4.0 readiness, including the breadth and depth of the utilisation of various Industry 4.0 technologies, the smartness of products, the digitalisation of transactions (with customers and partners), the integration of digital technologies in the production process ('operations'), the breadth and depth of data-driven decision-making and the extent of integration of digital technologies in corporate practices, standards and business models. Maturity models also include indicators quantifying employees' competencies and readiness to work in an Industry 4.0 environment and indicators evaluating the sophistication of management strategy regarding digitalisation.

These studies apply five or six stages describing the levels of Industry 4.0 maturity ranging from basic level (in the technologies and processes dimensions, this refers to the isolated deployment of IT-embedded solutions and partial connectivity) to full implementation (i.e. fully-digitalised production systems featuring horizontal, vertical and end-to-end integration of processes, functions and activities, and which allow for self-optimisation and self-adaptation).

It is important to bear in mind that selected dimensions of maturity are not relevant, or are only partially so, for manufacturing subsidiaries. For example, the dimension of 'customers' (use of customer data, digitalisation of sales) does not apply, since this belongs to the authority of the HQ. In a similar vein, local subsidiaries have no say in decisions about (transition to digital) business models. The dimension of 'products', referring to product data collection over the product lifecycle and the creation of digital product-services systems, applies only partially since the maturity stage in these dimensions is a function of HQs' strategic choices concerning whether to transfer the related activities and know-how to subsidiaries.

The dimensions that are relevant with respect to subsidiary-level Industry 4.0 maturity are 'operations', 'technology', 'management competences', 'culture' (e.g. knowledge sharing) and 'people' (the ICT competences of employees, the openness of employees to new technology and the autonomy of employees). Note that, as described below, our interview questions focused only on the 'technology' and 'operations' dimensions since the purpose of this research was not to evaluate the maturity of the surveyed companies but rather to explore the impact of investments on subsidiary upgrading. It is, therefore, beyond the scope of this paper to provide a detailed overview of the development levels pertaining to each stage of Industry 4.0 maturity. Firms were selected if they displayed at least stage 2 maturity in any of the indicators of these two considered dimensions.

The sample consists of 28 large, export-oriented companies, subsidiaries of global automotive companies and tier one suppliers operating in Czechia, Hungary and Poland.[5] Our aim to include local subsidiaries of the same lead companies from each country was only partially successful: the sample includes two subsidiaries of the same mother company operating in Poland and in Hungary; two others operating in Poland and Czechia; and two instances of subsidiaries operating both in Czechia and in Hungary. Table 1 summarises the specifics of the empirical data.

Table 1 **Empirical data collection**

	Czechia	Hungary	Poland
Number of firms interviewed	12	10	6
Additional interviews with employer organizations and trade unions	Representatives of an employer association and sectoral unions	Representatives of (1) Metalworkers Federation; (2) Association of Hungarian Automotive Component Manufacturers	A representative of a trade union federation and a tier one supplier (informing about general Industry 4.0 trends and the maturity of Polish firms)
Interviewees	TU (5), IT manager, division manager (logistics), technology officer, Industry 4.0 specialist	CEO, CTO, director of operations; TU (2), HR (2), other*	TU (2); director of production/operations (3); director of a division

* 'Other' includes an Industry 4.0 project officer, a digital engineering team leader, a chief information officer and representatives of the work council
HR = human resources officer; TU = trade union representative; CTO = chief technology officer; CEO = chief executive officer

The interview protocol, consisting mainly of open-ended questions to facilitate exploration, was designed around three[6] main topics: (1) the specifics of the Industry 4.0 technologies adopted by the given companies; (2) the motivations of the surveyed firms' investments in advanced manufacturing technologies; and (3) the developmental outcomes of digital technology implementation. Regarding this latter issue, the questions were intended to explore whether and how DT fosters upgrading; and whether it can produce any changes in the GVC role of the given subsidiaries. Finally, we also asked whether interviewees expect any changes in the location advantages of factory economies as a result of DT.

5. Data collection and analysis was conducted by Monika Martišková in Czechia, Kristóf Gyódi and Katarzyna Śledziewska in Poland, and Andrea Szalavetz in Hungary.
6. Only the topics included in this summary chapter are referenced here. There were additional questions with regard to the impact of digital manufacturing technologies on employment and the nature of work. These questions and the related findings are discussed by Monika Martišková in chapter 8.

Interviews were conducted between January and March 2018; and, since the implementation of Industry 4.0 solutions has intensified only recently, a period of five years (between 2013 and 2017) was selected as the period for which survey data would be gathered.

Interviews lasted thirty to ninety minutes. Multiple data sources, including press releases, corporate websites, business press articles, company reports and notes to the financial statement have been employed in order to triangulate the findings. Detailed descriptions of each case formed the basis of within-case and cross-case analysis (Eisenhardt 1989). This made it possible to cross-check interviewees' remarks regarding specific issues and identify consistencies or contradictions.

The main limitation of this case study analysis is the small size and the biased nature of the sample, consisting of companies operating in an industry that is a digital forerunner. Consequently, although the conclusions drawn from the insights obtained during the interviews may not be generalisable, the research has considerable value in terms of the insights it offers into the future for automotive manufacturing subsidiaries located in CEE under the impact of digitalisation.

4. Results: Descriptive analysis

4.1 Adoption of digital manufacturing technologies

On average, the surveyed companies display a relatively high degree of Industry 4.0 maturity; at least, in the light of the low average performance of business digitalisation in these countries.[7] Nevertheless, the breadth and depth of digital technology adoption is highly heterogeneous across the sample.

The activity mix of the companies interviewed is a mixture of highly automated and manual/semi-manual activities. Processing is, in most cases, fully automated and manual workers load and discharge the machinery. The individual components of the production system are of a heterogeneous level of technology. Less than half of the sample companies reported that they employ collaborative robots or driverless in-plant transport systems (AGVs). The managers interviewed explained the lack of AGVs with reference to space constraints in their factories and pointed out that new, greenfield facilities are already designed in a way that would permit extensive robotisation. Nevertheless, the companies had started to invest in industrial and service robots, employing them in processing activities (e.g. welding, cutting and painting), assembly, warehouse management and materials handling.

7. 'Average performance' denotes the business digitisation performance score of the Digital Economy and Society Index, specifically the percentage of enterprises using electronic information sharing, social media, big data analytics and cloud solutions. According to the most recent data (DESI 2019), Hungary and Poland scored among the lowest in Europe in terms of the integration of digital technologies (Hungary was 27th, Poland 25th and Czechia 23rd in the EU-28 (DESI 2019). Hungary scored also quite lowly in terms of the share of enterprises using industrial or service robots (just 3 per cent) (Eurostat: https://ec.europa.eu/eurostat/web/products-eurostat-news/-/DDN-20190121-1).

Over and above these basic and isolated, albeit spectacular, manifestations of Industry 4.0 technologies, the surveyed companies have all progressed along the stages of the connectivity of production processes and business functions (such as inventory management, material flows and maintenance). Process data are extracted and, in the case of the more developed half of the sample, fed into the manufacturing execution system. Production status and key performance indicators are visualised and, in about 25 per cent of cases, even analysed (through embedded analytical solutions) for data-driven decision-making.

On average, the managers interviewed have adequate knowledge of Industry 4.0,[8] albeit the heterogeneity of the sample applies in this respect as well. Accordingly, over and above robots, they would mention the term cyber-physical system, i.e. mechanisms to generate, capture, store and process data in order to improve the performance of operations. Additionally, interviewees reported that some production-related business functions are digitally supported. Examples of smart solutions include the real-time tracking of production processes, dashboard-based visualisations of key performance indicators, intelligent production monitoring systems, data-driven production scheduling, machine vision-based quality testing and predictive maintenance solutions. Some informants reported investment in the harmonisation of their own IT systems and that of their tier one and tier two suppliers so that lead companies could gain a real-time overview of processes along the whole supply chain.

Most of the respondents pointed out that DT is a long and gradual journey. Currently, smart technologies are integrated in legacy shop floor environments – in a way to avoid any disruptions or disturbances in ongoing production that is running at full capacity. Transforming a ‘running’ production system, however, poses formidable difficulties, as illustrated by the following interview excerpt.

> ‘It is not only our inability to finance the costs of investing in digital solutions. You know, we are running at full capacity and do our best to meet the deadlines and produce the required volumes. We simply do not have the capacity to engage in a lengthy exercise of screening our processes, elaborating a DT plan, looking for technology suppliers, interacting with them, restructuring the processes and implementing the new solutions.’

Moreover, since different activities are controlled by different software solutions, the harmonisation of heterogeneous legacy systems is indispensable to enabling data integration and the interconnection of all activities and processes. This is a precondition of the transition to Industry 4.0 – from the current ‘Industry 3.0 +’ environment prevailing in the dominant majority of firms in the sample. As a rule of thumb, it was found that the newer the production site, the more digitally mature it is.[9]

8. However, only four of them have an overarching, subsidiary-level DT strategy in place.
9. Some companies have already started to invest in the automation of data analytics and even in the implementation of artificial intelligence solutions, for example, as a means of identifying the correlation between the various monitored processing parameters and product quality; or have developed predictive analytics solutions to avoid machine failures.

Figure 2 summarises sample companies' investments in Industry 4.0 technologies. Note that not even the most developed companies can be classified as having achieved stage 4 maturity. Although these companies are experimenting with, or have introduced, selected stage 4 solutions, they are still far from displaying the maturity level that characterises stage 4 companies. Characterised by a compressed development towards digital maturity, these companies would be implementing both stage 3 and stage 4 investments. Moreover, the dominant majority of sample companies is in the process of implementing stage 2 and some stage 3 investments. Inter-country differences – the Hungarian companies in the sample feature much higher Industry 4.0 maturity than do the Czech or Polish ones – are the result of biased sample selection rather than reflective of a higher preparedness among Hungarian companies to embrace digital technologies (cf. Nick *et al*. 2019).

Figure 2 **Examples of investments in digital technologies in surveyed companies, classified according to associated maturity level**

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- Production control through cyber-physical systems, manufacturing execution systems;
- Paperless shop-floor management, digital production planning, predictive maintenance;
- Inventory management through radio frequency identification technology, digital simulation of processes for optimisation.

3

- Visualisation of production status based on real-time data analytics, robotic process automation (e.g. of quality control);
- Advanced internal connectedness.

2

- Factory automation, collaborative robots, automated material handling, automated guided vehicle;
- Data collection through cyber-physical systems, harmonisation of legacy IT systems.

Notes: Stages of digital maturity: 1. No industry 4.0 (only factory automation, including older generations of fenced robots); 2. More advanced solutions working in an isolated environment co-existing with legacy machinery; 3. Connection of value adding components; digital monitoring; 4. Production control through cyber-physical systems; 5. Completely automated factory (e.g Adidas' Speedfactory). Manufacturing execution systems are software packages used to manage factory floor material flows; track and optimise labour and machine capacity; provide real-time information about inventory and orders; and optimise production activities. Note that the integration of shop floor data and those from the enterprise system, implying automated data and information exchange, has been implemented in only a few companies.
Source: Author's compilation based on interview insights

4.2 Motivation to invest in digital technologies

Apart from the integration of digitally connected, autonomous robots in the production system and the automation of selected support functions (robotic process automation), most of the above-listed digital solutions aim at obtaining insights that support interventions in complex manufacturing processes and achieving better control of operations.

Companies in the sample have decided upon the automation of core and the digitalisation of support functions in an effort to resolve the problem of labour shortages; enhance the quality, flexibility and transparency of operations; and improve productivity and process efficiency. Some of these motivations are interdependent. For example, increased transparency allows a rapid reaction to process anomalies, which improves process efficiency. The real-time measurement and visualisation of process parameters improves not only transparency, and thus enables data-driven decision-making, but also allows for process optimisation e.g. through the reduction of internal transport or of work in progress. In this vein, transparency contributes to process efficiency improvement.

As the following interview excerpts illustrate, companies adopt nuanced, context-specific approaches when they decide on investment in digital technologies.

> 'Augmented reality tools and virtual simulation? No, we do not have such things here: it is simply not needed. Factory planning is performed at central locations. Planners use advanced digital factory planning solutions, such as the virtual simulation of plant layout and material flows. We simply implement the received plan, correcting and modifying it if necessary, but this kind of work does not require advanced digital solutions here.'

> 'I visited a partner subsidiary in Italy. It is equipped with the most advanced production equipment and Industry 4.0 solutions: with everything that we would just love to have. Obviously, we have to admit that much higher value added products are manufactured at the Italian subsidiary: net sales per employee are four times as high as in Hungary! They have the wherewithal to invest in these technologies.'

> 'Previously the only factor we considered when deciding about the automation of a specific task was the return on investment. Now, over and above costs and return, we consider many more factors: availability of workforce; operator workload; and ergonomics.'

Technology upgrading through digital solutions was, in some cases, initiated by parent companies prescribing that cloud-based solutions or paperless factories should be implemented throughout the whole corporation. Most often, however, subsidiaries themselves decided on the specifics of digital technology deployment. Subsidiary managements face a 'digitalisation imperative' in a similar vein to headquarters. However, in the case of headquarters, DT is about strategic differentiation and business model innovation, since it strengthens the competitive advantage and enables additional revenue generation (Szalavetz 2019b); whereas in the case of manufacturing subsidiaries, the imperative of process upgrading through digital solutions is driven by parent companies' non-abating pressure to cut costs, increase efficiency, reduce cycle time and improve both the flexibility and the excellence of operations. Subsidiaries are thus encouraged to suggest and deploy digital solutions that would result in quality improvements and/or cost savings and enable a prompt and flexible response to new requests.

As these interview excerpts illustrated, subsidiaries have to finance these investments themselves, which is compounded by the requirement to have their DT projects accepted by parent companies. A Polish interviewee pointed out that a 'Catch-22' situation applies in this respect: the relatively low local wage level delivers a lower return on investment than that of DT projects in high-wage economies. Nevertheless, increasing local wages, growing labour shortages – also in low-cost locations – and customer expectations in terms of customisation, quality and delivery times make lead companies more inclined, even in factory economies, to acknowledge the 'robot dividend' (cf. Huang and Sharif 2017).

4.3 The developmental outcomes of digital transformation – impact on subsidiaries

Our interview results indicate that the implementation of digital technologies has contributed to process upgrading in the surveyed companies – a precondition for survival amidst inter-subsidiary competition for resources and lead companies' aims to streamline their supplier base. Manufacturing subsidiaries have been facing continuous pressure to increase productivity and resource efficiency and to reduce the costs of their operations. Above a certain threshold, however, this has proven to be increasingly difficult to achieve – at least with traditional methods. The deployment of digital technologies has opened up a whole range of opportunities for the further improvement of the required indicators.

Moreover, increased digital maturity and the resulting improved efficiency and quality were 'rewarded' by parent companies delegating more sophisticated production tasks than previously (entailing product upgrading). Note that product upgrading is the outcome of parent companies' strategic decisions; subsidiaries have no say in determining the composition of the product mix they manufacture.

About half the managers we interviewed spoke about DT-related functional upgrading, highlighting that they have been assigned new and relatively more advanced tasks than previously. Some local production units have obtained 'product mandates' i.e. full responsibility for the further development of the products (e.g. specific components) they manufacture and regarding the improvement of the related production processes. Engineers in these companies have been assigned new tasks, such as product design, simulation and software development, for example as regards the development of the manufacturing execution system. They have been involved not only in analysis of production technology malfunctions but have also been entrusted with process development. Lead companies have delegated particular R&D activities to subsidiary level: as corporate global R&D has become increasingly complex and multi-faceted, subsidiary researchers and engineers have been assigned partial R&D tasks to be rolled out to partner subsidiaries once completed.

Most of the new functional assignments which had been delegated to subsidiary level were related to the increased 'softwarisation' of production and support processes. New knowledge-intensive assignments have contributed to subsidiaries' accumulation of technological capabilities through learning-by-doing (Szalavetz 2019a).

Despite non-negligible achievements in the field of cost efficiency, operational excellence and functional upgrading, the value chain position and autonomy of the surveyed subsidiaries have barely changed. These companies were, and remain, manufacturing units within the global organisation of their parent companies, subject to hierarchical governance that has not changed. Although some subsidiaries have acquired the status of a competence centre, local autonomy has failed to increase in a meaningful way. Investments in digital technologies have been decided upon according to the same organisational mechanism as previously: a combined top-down and bottom-up budgeting procedure. Subsidiary initiatives were accepted if, and only if, local subsidiaries were in a position to cover the associated expenses, including the financing (i.e. the hiring) of the staff involved in the development and deployment of the new solutions. This has proved to be a remarkably hard constraint which has, in a number of cases, hindered subsidiaries' digital upgrading.

In other instances, the costs of subsidiary initiatives aiming at introducing advanced digital solutions have (partially) been covered by parent companies; however, only if the subsidiaries could prove that return on investment would be rapid, usually in less than one year.

In addition to establishing a complete lack of digital upgrading-driven changes in subsidiaries' position in the value chain, it is worth investigating whether their increased digital maturity, the resulting process upgrading and the accompanying functional upgrading had any beneficial impact on basic corporate (subsidiary-level) performance indicators. Our interview results indicate that, although both employment and revenues grew considerably in the companies in the sample, these developments were not necessarily associated with investments in digital technologies. The improvement in performance indicators was, rather, driven by capacity expansion and explained by the upswing in the business cycle; that is, by increasing demand for the products manufactured by the local subsidiaries in the survey. Obviously, enhanced digital maturity contributes to subsidiaries' ability to cope with higher quantitative and qualitative requirements. Altogether, it appears that the impact of digital upgrading on subsidiaries' performance indicators is beneficial, albeit only in an indirect manner.

5. Discussion and concluding remarks

The insights obtained from the companies interviewed suggest that the probability of the pessimistic scenario, outlined in the introductory section, is quite low. In the period covered by our survey, production expanded considerably in the companies in the sample and this was accompanied by investments in tangible (advanced production technology) and intangible assets. Since new production equipment already integrates advanced digital technologies, investments in the harmonisation of the IT system and the deployment of a manufacturing execution system were also considered indispensable.

Capacity expansion has brought to the fore the pressing labour shortages that local companies have already been facing for several years. In order to prevent labour shortages from becoming a bottleneck to further capacity increases, additional investments have been made in the automation of production and support processes, i.e. in the deployment of advanced robotic solutions.

These developments have led to upgrading along various dimensions, including process and product upgrading, as well as functional upgrading driven by parent companies delegating increasingly advanced tasks to subsidiary engineering teams.

These positive developments notwithstanding, there are some considerations that call for caution.

Above all, we should note that these developments can, in part, be interpreted as a lucky coincidence since the period under survey coincided with the longest upswing in the automotive business cycle (Collie *et al.* 2019). Rapidly increasing demand prompted investment in expanding the production capacity of lead companies' existing manufacturing facilities and driving operational effectiveness through the implementation of digital solutions. It was partly the path dependence originating in global automotive companies' past investment decisions, coupled with the upswing in the automotive business cycle in the second half of the 2010s, that gave an impetus to the gradual transition towards higher Industry 4.0 maturity in manufacturing subsidiaries in CEE.

Furthermore, despite these unambiguously positive developments, the following paragraphs argue that some of the anticipated DT-driven adverse effects may well materialise, albeit later and more gradually than the projections of technological alarmists.

First, further investments are expected that will increase the level of automation in the subsidiaries we examined. These investments are driven partly by the necessity to keep up with competitors implementing advanced technology and partly by the decreasing price and dramatically improved features of robotic solutions. Another reason is that the existing semi-automated or manual production technology in CEE is aging towards obsolescence. The next phases in the evolution of the manufacturing facilities we surveyed will be marked by a gradually increasing share of automated processes, replacing the current manual or semi-manual, labour-intensive stages in subsidiaries' production systems. This will by itself have a sizable labour-saving effect, triggering technological unemployment.

Alternatively, with persisting labour shortages, in particular regard to skilled maintenance staff, robot programmers and engineers, investors will reconsider the locational advantages of their existing manufacturing facilities. Note that DT is bound to reduce the importance of one of the important existing locational advantages for CEE: the flexibility of the local labour force. Industry 4.0 technologies not only reduce the labour-intensity of production but they also make existing production systems adaptive, flexible and reconfigurable (Váncza *et al.* 2011).[10] If technological solutions

10. It is, in particular, the modular organisation of the shop floor, a technological and organisational change accompanying digital transformation, that has enabled production systems to become flexible and reconfigurable. Modular organisation at the shop floor refers to the ease of adding new components to, or subtracting obsolete ones from, the production system without the need to redesign the entire system or the specific production process.

enable production systems to adapt to changes in the external environment without major increases in costs or reduction in throughput, the importance of labour flexibility – that is, driven by lenient workplace regulation in CEE – will be reduced.

Revisiting past location decisions seems inevitable also because manufacturing facilities in headquarter economies are also being upgraded by advanced manufacturing technologies, and these latter investments are being supported by a variety of generous policy instruments. Industry 4.0 technology-based capacity expansion in advanced economies – brand new assets representing advanced digital production technology – may effectively squeeze out existing low-cost production facilities, while there will be no need even to backshore the previously relocated, old capacities.

The timing of these developments is difficult to predict.

For example, the timing of the transition to advanced automation and robotic techniques at the surveyed companies (and at other automotive subsidiaries in CEE), implying a reduction of labour intensity and, eventually, technological unemployment, is a function of the depreciation of existing legacy assets. Past investments have created significant path dependence; consequently, a hasty transition to advanced manufacturing technologies would involve prohibitively high adjustment costs (in that case, existing assets would need to be written off).

Apart from physical and technological obsolescence, the timing of asset replacement is also influenced by the development of adjacent technologies. For example, advances in materials science call for advanced processing technology: lightweight metal can be more reliably processed and welded by automated technology. Other moderating factors include workplace regulation and the intensity of competition. Compliance with occupational health and safety regulations – or, more broadly, with good manufacturing practice – requires an increasing use of advanced and smart technologies on the shop floor (e.g. remotely controlled robots in painting and welding, or collaborative robots in materials handling). Competition and customers' ever-increasing expectations, again, require the implementation of digital technologies to increase flexibility and responsiveness.

The probability of the other development, according to which modern, automated and digitally upgraded production facilities in advanced economies render local capacities obsolete, is a function of three factors: 1) the pace and the direction of the development of technology; 2) the business cycle; and 3) political pressure for reindustrialisation in advanced economies compounded with generous policy support.

Regarding the first factor, the emergence of a new dominant design among competing alternative powertrains may accelerate the obsolescence of some already-outdated production facilities in CEE. In a similar vein, the imminent automotive downturn (Collie *et al.* 2019) is bound to intensify the consolidation of the industry. When capacities are aligned with demand, under-digitalised and underperforming plants are the first ones to be closed. Furthermore, support programmes subsidising investment in smart factories in advanced economies, and the associated political pressure for reindustrialisation, may effectively shepherd the selection and retention strategies of lead companies.

Interview evidence also indicates another cause for concern, namely that the structure of value creation has barely changed in CEE. There are no signs of CEE actors shifting to a high-road development path in which specialisation in advanced activities and increasing unit value added would provide a major impetus to growth.

On the one hand, functional upgrading, the uptake of relatively more advanced, higher value added activities has undoubtedly intensified at some of the companies in our sample. Functional upgrading has fostered global companies' local commitment and their willingness to relocate further and more technology-intensive production to their manufacturing sites in CEE. The positive effects of previous functional upgrading will certainly be reinforced by subsidiaries' implementation of digital technologies.

On the other hand, however, functional upgrading has not given a significant impetus to local growth (cf. Milberg and Houston 2005). Global companies' investments in capacity expansion, upgrading and their relocation of additional production activities have remained the main engines of growth in the surveyed period, dwarfing the growth effects of functional upgrading.

In summary, while there are no signs of DT-induced new drivers of growth, the traditional engines of growth in CEE factory economies are becoming increasingly prone to erosion.

Consequently, it is safe to argue that the observed beneficial developments cannot prevent, but only delay, some of the adverse effects of DT becoming manifest. The surveyed period can best be described as a 'lull before the storm'.

Interview findings and the resulting considerations have important managerial and policy implications. The surveyed companies – similarly to other manufacturing subsidiaries in factory economies – need to navigate between a rock and a hard place. Evidently, investing now in automation and advanced digital solutions is the better option, even if it entails some labour shedding, since increased digital maturity is the precondition (but not the guarantee) of longer-term survival. Holding steady with unchanged technology may keep the existing workforce in the short-term, but the looming downturn in the business cycle will probably hasten parent companies' adverse location decisions.

At the same time, policy-makers need to recognise that DT-driven devastating technological unemployment is not fate – not even in those countries that are more exposed to the disruptive effects of DT than others. Well-conceived public policy can improve societies' adaptation to the shifting demand for skills. New approaches and policy innovations are required in factory economies to enable a higher-road development trajectory than the one enabled by a simple attraction of efficiency-seeking foreign direct investment.

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