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Book

The challenge of digital transformation in the automotive industry : jobs, upgrading and the prospects for development

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Edited by
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Chapter 1
Introduction: Digitalisation and automotive production networks in Europe

Jan Drahokoupil

This edited volume analyses the challenges of digital transformation, typically discussed under the heading of Industry 4.0, from the perspective of production locations. Digital transformation represents a dual challenge from such a perspective.

First, production locations face a fundamental challenge as far as their role in the production network is concerned. Increased automation may undermine competitive advantage in terms of lower labour costs and more flexible labour market arrangements. New technology may also replace the more knowledge-intensive tasks conducted by engineers in production locations, leading to the effective downgrading of the position of manufacturing units in the value chain. At the same time, digital technologies may support the decentralisation of advanced activities across the production network, allowing production sites to be upgraded through advanced manufacturing technologies.

Second, there is the jobs challenge. It has been particularly noticed that countries specialising in production are particularly vulnerable to the job displacement effects of new technologies as many of the tasks in which they specialise can be automated. However, new technology also changes the nature of work in production. This entails changes in the nature of the skills required from workers and the autonomy they have in carrying out tasks, and also in work intensity.

The digital transformation of production is associated with so-called Industry 4.0 technologies. These combine data analytics, the Internet of Things and production machinery into cyber-physical systems. The list of technologies associated with Industry 4.0 includes industrial sensors, robots and collaborative robots (cobots), predictive analytics, machine learning, autonomous in-plant logistics, simulation, augmented and virtual reality, wearables and 3D printing. However, the distinctive feature is the networking between humans and both physical and digital industrial production processes throughout the value chain. The integration of physical and digital production, together with continuous and real-time analysis, should improve the optimisation of production, resulting in a more flexible and efficient production process (WEF 2014). Improved profitability can be achieved by value creation through an improved product offer (flexibility), asset utilisation (optimisation) and reduced labour costs (automation).

This book addresses the twin challenges of digital transformation by analysing the impact of new technologies at company level. It focuses in particular on the automotive industry which has been at the forefront of introducing new technologies such as industrial robots. We analyse their impact on working conditions and employment as well as on the role of production sites in the value chain. The book also addresses the extent to which digital transformation represents an opportunity, or a challenge, for the countries that specialise in manufacturing production as far as their development prospects and competitiveness are concerned.

The automotive industry in Europe is characterised by a division of labour – organised by a few multinational corporations (MNCs) – between headquarters locations where production is collocated with business and technology development and other intangible activities; and peripheral sites that specialise in production activities. The tradition of industrial peripheries in the automotive sector encompasses Spain, where automotive production continues to play an important role. In Italy, while still characterised by the presence of headquarters functions, product specialisation has also moved towards that of a peripheral location. More recently, in the context of EU enlargement, a large part of automotive manufacturing has been relocated to central and eastern Europe (CEE), which now constitutes the European industrial heartland as far as production activities are concerned.

These challenges in the automotive industry are addressed through case studies of old and new peripheries in the European automotive industry. The case studies presented in individual chapters were conducted within an ETUI research project on digitalization in production. The project primarily examined MNC affiliates, including both original equipment manufacturers (OEMs) and their suppliers. We focused, in particular, on leaders in the implementation of Industry 4.0 technologies. However, the attention on MNC affiliates is complemented by two studies covering domestic companies. These include both suppliers of simpler components and digital entrepreneurs providing high-end services to automotive companies. An overview of the countries and companies covered in this book is provided in Table 1.

Table 1 **Case studies**

MNC headquarters (Chapter 2)	
Germany	2 OEMs (125,000/670,000 globally); 2 technology suppliers (8,000/20,000 globally)
MNC affiliates (Chapters 3, 4, 7, 8)	
Czechia	3 OEMs (2,248-22,932); 7 Tier 1 suppliers (726-9,000); 2 Tier 2 suppliers (203-848)
Hungary	3 OEMs (1,251-11,803); 7 Tier 1 suppliers (266-4,827)
Poland	3 OEMs (1,876-8,020); 3 Tier 1 suppliers (1,219-7,183)
Spain	1 OEM (4,800); 8 Tier 1 suppliers (50-280)
Italy	4 Tier 1 suppliers (394-10,300); 1 Tier 2 supplier (226)
Domestic companies (Chapters 5, 6 and 7)	
Hungary	12 digital entrepreneurs (2-182)
Poland	3 Tier 1 suppliers (200-450); 3 Tier 2 suppliers (50-250); 6 digital entrepreneurs (50-250)
Italy	1 Tier 3 suppliers (413)

Note: employment levels in 2018 in brackets (for Poland: 2017, Spain: 2019)

The book starts with a chapter by Pamela Meil that analyses digital transformation in the automotive industry from the perspective of the headquarters of major German automotive MNCs. The volume then covers the impact of digital transformation in both the old and new peripheries of the automotive industry in Europe. Four chapters address the competitiveness challenge: does digital transformation undermine or enhance the upgrading prospects of companies participating on the peripheries of the automotive value chain? In this section, Andrea Szalavetz and Ricardo Aláez-Aller, with his colleagues, analyse the impact on MNC affiliates in CEE and Spain respectively. The chapter by Krzysztof Gwosdz and his colleagues contrasts the situation of MNC affiliates, typically assemblers or tier one suppliers, with that of domestic companies in Poland. The latter are typically tier two suppliers specialising in simpler products. Andrea Szalavetz supplements the analysis of domestic companies with a chapter that focuses on the role of domestic technology leaders engaged in providing software solutions to automotive companies, investigating the extent to which they could compensate for the lack of high-value activities in the automotive value chains in peripheral regions.

Finally, there is a section on the jobs challenge. What is the impact of introducing new technology on working conditions? How does the demand for occupations and skills change? How have trade unions addressed the challenges? The chapters by Matteo Gaddi and Monika Martišková present findings on these developments in MNC affiliates in Italy and CEE, respectively.

The remainder of this chapter discusses some of the key findings. Before addressing each of the challenges, it provides an overview of the position of CEE and southern Europe in automotive production networks and the role of Industry 4.0 technologies.

1. Automotive production networks, European industrial peripheries and Industry 4.0

Production networks in the automotive industry are characterised by a hierarchical structure in which multinational corporations play a major role. A handful of OEMs, such as the Volkswagen Group or the PSA Group, develop final products, assemble vehicles and organise supplier relations in the production network. Moreover, these carmakers now rely on a relatively small number of large supplier firms that dominate tier one supply operations and with which they have thus forged close relationships based on interdependence. They share some research and development functions and are closely interlinked through the just-in-time, lean production model. As shown in detail in Chapter 7 by Matteo Gaddi, new technology facilitates horizontal integration along the value chain, allowing OEMs, or upper-tier operators, to monitor and directly control production processes in supplier firms to the level of the specific tasks conducted by individual workers.

There is a complex geography where business relationships often span the globe. At the same time, a distinct regional division of labour has emerged at the level of world regions such as Europe. Within these regions, there is a hierarchy between core locations where the headquarters of MNCs are located and peripheral locations that specialise in production functions. Importantly, carmakers as well as global suppliers tend to locate R&D activities related to vehicle development in their core locations; R&D in peripheral locations is typically geared towards production support. OEMs place assembly and production functions in the periphery to take advantage of lower labour costs. Given the large sunk costs and dependence on regional supplier networks, assembly activities tend also to stay in place once labour costs rise. The same applies also to bulky, heavy and model-specific parts production that needs to be concentrated close to final assembly plants to assure timely delivery at reasonable cost (for example engines, transmission, seats and other interior parts). At the same time, lighter, more generic parts can be produced at a distance and are likely to be relocated to take advantage of scale economies and low labour costs (for example tyres, batteries and wire harnesses).

In Europe, Germany represents the key core location in automotive production networks. It is home to major OEMs, most notably the Volkswagen Group, as well as to global supplier firms such as Bosch. As shown in Table 2, the automotive industry also plays an important role in the overall economic structure. In 2017, more than 845,000 workers were employed in the narrowly-defined automotive sector in Germany (NACE2 C29 in FTE, Eurostat, sbs_na_ind_r2), but a broader classification would cover about two million industrial workers. A much lower share of components indicates that Germany specialises in core functions. Many production activities remain located in Germany, as a further result of the political sensitivities involved in relocation, but these production functions are more tightly integrated with R&D functions (Krzywdzinski, 2017). As a core location, Germany specialises in higher-end larger models; at the same time, the Volkswagen Group enjoys considerable flexibility in locating production models across its European sites. Importantly, carmakers tend to introduce production of new electric models in Germany and at other core locations (Drahokoupil *et al.* 2019, see also Chapter 2 in this volume).

Table 2 **Automotive: value added and employment, 2017**

	Share in non-financial business economy,* %		Share of components in automotive, %	
	Value added	Employment	Value added	Employment
Slovakia	8.2	50.7	4.8	69.4
Czechia	**8.2**	**50.3**	**4.8**	**75.5**
Hungary	**7.2**	**47.6**	**3.6**	**75.3**
Romania	6.4	82.2	4.6	89.1
Germany	**6.0**	**22.7**	**2.9**	**31.7**
Sweden	3.6	17.9	2.4	26.4
Poland	**3.3**	**67.4**	**2.2**	**77.9**
North Macedonia	3.2	NA	NA	NA
EU27	*3.2*	*32.9*	*1.9*	*NA*
Slovenia	3.1	52.5	2.3	63.4
EU28	*2.9*	*31.7*	*1.8*	*50.3*
Serbia	2.6	69.7	2.9	85.4
Spain	**2.3**	**41.3**	**1.3**	**48.5**
France	2.0	36.5	1.4	42.2
Italy	**2.0**	**46.8**	**1.2**	**53.1**

Notes: EU and candidate countries where automotive share of valued added in non-financial business economy > 2 per cent. Countries that are considered in this project are in bold. Automotive refers to NACE2 C29: Manufacture of motor vehicles, trailers and semi-trailers, components; and to NACE2 C293: Manufacture of parts and accessories for motor vehicles.
* Total business economy; repair of computers, personal and household goods; except financial and insurance activities.
Source: calculated from Eurostat [sbs_na_ind_r2, sbs_na_sca_r2]

A large share of components characterises the peripheral producers (see Table 2). Southern Europe, and Spain in particular, represents the traditional peripheral location in the European automotive industry. Italy, the home of major carmakers, predominantly FCA/Fiat, has traditionally enjoyed the status of a core automotive location. However, with the plight of FCA/Fiat, vehicle production has declined substantially while the share of components has risen, and many Italian automotive companies now primarily supply carmakers in western Europe, especially Germany. The product specialisation of Italy has thus moved towards that of a peripheral producer. The integration of CEE countries into European production networks in the context of EU enlargement has changed the geography of production in Europe (Leitner and Stehrer, 2014 see also Chapter 2 in this volume). CEE countries have become firmly established as key production locations while automotive employment in all west European countries has shrunk (Pavlínek 2019). As shown in Table 2, many CEE countries now rely more heavily on the automotive industry than Germany. While Spain has been largely able to retain its position as a key assembly location, it has missed out on all greenfield investments in assembly plants in the last thirty years (Aláez-Aller *et al.* 2015). In Italy, FCA/Fiat joined German and French carmakers in opening production locations in eastern Europe (Poland and Serbia). Moreover, Italian component makers now compete with CEE companies when supplying German carmakers. Among the CEE countries, the share of components in automotive employment is highest in Poland. The latter, as discussed in Chapter 5, somewhat lags behind Slovakia, Hungary, and Czechia as far as the integration into automotive production networks and technology deployment are concerned.

Production networks in peripheral locations have a dual structure, with foreign ownership having the structuring role as far as the nature of value adding activities is concerned. Foreign-controlled OEMs and upper-tier supplier companies exhibit higher value added and complexity, and account for most of the R&D (e.g. Radosevic and Ciampi Stancova 2018; Knell 2017). Domestic companies tend to be integrated into global production networks as lower-tier suppliers specialising in simpler activities. At the same time, however, the higher value added functions in foreign subsidiaries tend to be weakly developed, with most R&D-related activities concentrated in the core locations (Pavlínek 2016; cf. Drahokoupil and Fabo 2020). Innovation therefore tends to be restricted to the upgrading of the production process rather than R&D (Szalavetz 2017a). In Spain, for instance, MNCs do not develop R&D activities related to product development; such activities can be found only in automotive suppliers with domestic capital (Aláez-Aller *et al.* 2015). Two parallel innovation systems can thus be identified (Radosevic *et al.* 2010). There is a large FDI-centred system, targeted towards downstream activities in production such as the development of production processes. In contrast, domestic innovation activities, however weak, are R&D based: they comprise a handful of new technology companies specialising in knowledge-intensive services.

Core locations are the first to introduce new technologies into their production processes. This is not surprising given that they also face higher labour costs and where the return on automation based on labour saving is thus higher. The level of automation in manufacturing, measured by the number of multipurpose industrial robots per 10,000 people employed (see Table 3) is indeed highest in Germany as far as the EU is concerned. Peripheral producers exhibit much lower levels of automation. Italy ranks very high on this indicator, but this is driven largely by automation outside the automotive sector (see Table 4). In general, the automotive industry has been at the forefront of introducing digital technology and automation into production processes. As shown in Table 4, it accounts for the bulk of industrial robots in Europe. The level of robotisation in the industry is particularly high in Spain – relative both to comparable countries and to the rest of its industrial sector, reaching 88 per cent of the German level.

Table 3 **Number of multipurpose industrial robots per 10,000 people employed in manufacturing industry (ISIC rev.4: C)**

	2018	Growth 2013-2018
Germany	**338**	**20%**
Sweden	247	40%
Denmark	240	36%
Italy	**200**	**15%**
Belgium	188	18%
Benelux	184	51%
Netherlands	182	80%
Austria	175	52%
Slovenia	174	91%
Spain	**168**	**12%**
Slovakia	165	94%
France	154	22%
Switzerland	146	62%
Finland	140	9%
Czechia	**135**	**99%**
United Kingdom	91	32%
Hungary	**84**	**62%**
Portugal	68	62%
Norway	56	37%
Poland	**42**	**121%**
Greece	23	77%
Romania	21	200%
Estonia	19	217%
Croatia	7	75%
Singapore	*831*	*271%*
South Korea	*774*	*80%*
Japan	*327*	*3%*
China	*140*	*460%*

Note: EU and candidate countries where data available and selected comparator countries.
Countries that are considered in this project are in bold.
Source: International Federation of Robotics (World Robotics 2019 – Industrial Robots)

Table 4 **Number of multipurpose industrial robots per 10,000 people employed in automotive industry (ISIC rev.4: C29) and in all other manufacturing (ISIC rev.4: C excluding C29), 2018**

	Absolute			As per cent of German level	
	Automotive	Other Industries	Automotive to other ratio	Automotive	Other Industries
Slovenia	1371	91	15.1	108%	47%
Germany	**1268**	**195**	6.5	**100%**	**100%**
France	1239	102	12.1	98%	52%
Austria	1118	123	9.1	88%	63%
Spain	**1110**	**88**	12.6	**88%**	**45%**
Slovakia	815	41	19.9	64%	21%
Italy	**748**	**171**	4.4	**59%**	**88%**
Sweden	718	185	3.9	57%	95%
United Kingdom	687	46	14.9	54%	24%
Portugal	646	38	17.0	51%	19%
Czechia	**555**	**62**	9.0	**44%**	**32%**
Hungary	**369**	**46**	8.0	**29%**	**24%**
Poland	**189**	**29**	6.5	**15%**	**15%**
South Korea	2589	587	4.4	204%	301%
Japan	1165	245	4.8	92%	126%
China	732	70	10.5	58%	36%

Note: EU and candidate countries where data available and selected comparator countries.
Countries that are considered in this project are in bold.
Source: International Federation of Robotics (World Robotics 2019 – Industrial Robots)

The level of robotisation in CEE countries is much lower. At the same time, it has grown rapidly in the last five years. This can be attributed to rapidly increasing labour costs. In fact, as discussed in this volume, labour shortages represent the major motivation for investment in automation in the region. Interestingly, as argued by Monika Martišková in Chapter 8, when labour costs are taken into account the rate of robotisation in some CEE countries, Czechia and Slovakia in particular, is higher than average; although, in contrast, it is lower than expected in Poland, indicating the lower level of technology deployment which is consistent with the findings in that particular chapter (Chapter 5). The rate of robotisation in Germany is actually lower than what could be expected given its labour costs; conversely, it is much higher in South Korea, due largely to this country's position as an industrial technology leader.

The use of industrial robots, however, is an imperfect indicator of technologies discussed under the Industry 4.0 heading. In fact, the use of industrial robots is often better classified as Industry 3.0. Whereas the latter refers to the automation of manufacturing, Industry 4.0 entails the increasing digitalisation of the production process. In this context, as argued in Chapter 3, five stages of digital maturity can be distinguished. The first stage is Industry 3.0: automation with the use of older generations of fenced-off robots. In the second stage, more advanced solutions are introduced, but they are isolated and co-exist with legacy machinery. In the third stage, value adding components are connected for the purposes of digital monitoring. In the fourth stage, production is controlled through cyber-physical systems. Finally, in the fifth stage, production is completely automated. Adidas's Speedfactory represents an example of such a facility.

The key to Industry 4.0 is thus the increased connectivity of production processes and business functions (stages 3 and 4). The implementation of enterprise resource planning (ERP) systems is a key tool in achieving such connectivity and this can be taken as an indicator of Industry 4.0 maturity[1]. The share of enterprises that implement the ERP software package to share information between different functional areas in the countries analysed in chapters in this volume is presented in Table 5. The pattern largely corresponds to that of robotisation. The automotive sector exhibits a higher degree of Industry 4.0 maturity than the rest of manufacturing. There is variation between countries, but Germany does not stand out as it did in terms of robot intensity – the degree of implementation of ERP systems is similar to that in Spain, Czechia and Italy. In contrast, Poland and Hungary exhibit a lower degree of Industry 4.0 maturity.

Table 5 **Enterprises who have ERP software package to share information between different functional areas, %, 2019**

	Manufacturing	Automotive
Spain	51	NA
Germany	50	66
Czechia	48	68
Italy	45	62*
Poland	32	48
Hungary	20	44
EU27	47	60
EU28	46	59

Notes: countries covered in this book
10 or more people employed
*2014
Source: Eurostat [isoc_bde15dip]

The aggregate differences outlined here were not reflected in our sample. Respondents in the headquarters of German MNCs did not see the process of Industry 4.0 implementation in their companies as particularly advanced, indicating that automation will play a larger role in the future. They also pointed out that some of the most modern production technology is located in newly-opened plants in CEE. The case studies of MNC affiliates thus focused on companies that represented leaders in the implementation of Industry 4.0 technology. In our CEE sample, the most advanced Industry 4.0 technologies were found in Hungarian affiliates. Overall, MNC affiliates in CEE operated a mixture of highly-automated and semi-manual activities.

1. The implementation of the manufacturing execution system (MES), rather than that of the ERP, may be considered a more important indicator of Industry 4.0 maturity on the shop floor level in production locations. However, there is a lack of comparative data on the use of MES.

Figure 1 provides some examples of the technologies, classified according to Industry 4.0 maturity levels. The most advanced Industry 4.0 solutions involved production control through cyber-physical systems. These belong to stage 4 in our classification, but the deployment was rather experimental and none of the companies classified as having achieved a fully-fledged stage 4 maturity. The technology solutions included, for instance, automation of data analytics, also achieved through artificial intelligence solutions, to identify the process parameters having the largest influence on product quality. The integration of production functions through ERP systems, as discussed in Chapter 7 on Italian plants, allows the achievement of the objectives of the just-in-time lean production model in which production planning is pulled by customer orders, with customers gaining access to data about, and to control of, individual tasks assigned to workers. Technologies such as ERP systems and cobots have also been introduced in Spanish plants. At the same time, as argued in Chapter 4, we found that MNC affiliates exhibited a lack of purposeful strategies to take advantage of the full potential of stage 4 automation. Finally, as shown in Chapter 5 on domestic suppliers in Poland, many companies operating in the lower tiers of the supplier network effectively rely on manual labour and are thus yet to implement even an Industry 3.0 level of automation.

Figure 1 **Stages of digital maturity: examples of investments in digital technologies in surveyed companies**

5

Completely automated factory
– *Not in our sample*

4

- **Production control through cyber-physical systems**
– Manufacturing execution systems;
– Digital production planning, predictive maintenance;
– Inventory management through radio frequency identification technology.

3

- **Connection of value adding components; digital monitoring**
– Visualisation of production status based on real-time data analytics, robotic process automation;
– Advanced internal connectedness.

2

- **Advanced solutions, but isolated and co-existing with legacy technology**
– Collaborative robots, automated material handling, automated guided vehicle;
– Data collection through cyber-physical systems, harmonisation of legacy IT systems.

1

No Industry 4.0: factory automation using older generations of fenced robots

Source: adapted from Andrea Szalavetz (Chapter 3)

There is some coordination of Industry 4.0 projects at MNC level while corporate headquarters, as discussed in Chapter 2, may have a slight preference for launching innovative pilot projects at headquarters sites. However, competition between MNC affiliates is key to understanding the motivation for investing in Industry 4.0 technologies. As discussed in Chapters 3 and 4, MNC affiliates face continuous pressure from their parent companies to cut costs. They need continually to improve efficiency and flexibility. The initiative to implement Industry 4.0 technologies thus comes from local managements seeking to improve the competitive position of the affiliates. New technology may also allow them to achieve some strategic differentiation from other affiliates that they are competing with for the allocation of production and other projects. Moreover, in CEE, labour shortages were a key motivation for investing in automation. These were relevant for MNC affiliates in the upper tier of the supply chain and for lower-tier domestic companies alike.

A position in the periphery represents a constraint on the adoption of new technologies. More specifically, our case studies underlined the limited autonomy of MNC affiliates in capital expenditure discussions, with affiliates needing to seek the approval of their head office for such investments. It is typically required that any investment in new technology brings a rate of return that allows the costs to be recuperated within two years. Moreover, affiliates are normally expected to finance such investment from their own resources. Lower-tier suppliers, foreign or domestic, may therefore not be able to finance such investment since lower value added activities do not bring sufficient profit to plough back in the name of investment. Furthermore, as discussed in Chapter 5 on Poland, domestic suppliers also face broader barriers in terms of conservative attitudes towards technology, shortages in terms of competences and skilled staff and a lack of a culture of cooperation.

2. The competitiveness challenge

The digital transformation may provide an opportunity for peripheral locations to upgrade, moving to activities which offer higher value added and, hence, revenue. In an optimistic scenario, as discussed in more detail in Chapter 3, new technology increases the knowledge intensity of the production activities in which companies in peripheral locations specialise. Industry 4.0 technologies may facilitate the further decentralisation of advanced activities including engineering, design and software development across production networks. Digital transformation thus allows ‘factory economies’ (Baldwin 2013) to accumulate technological and R&D activities that have been traditionally located in core, headquarters locations.

However, such a scenario can be contrasted with a pessimistic one involving downgrading and the loss of existing competitive advantages. Accordingly, Industry 4.0 technologies may automate some of the knowledge-intensive activities performed by engineers in production locations (Flecker and Schönauer 2016; Szalavetz 2017a). For instance, process development can be automated through self-optimising solutions embedded in cyber-physical systems (see Chapter 3). Crucially, as emphasised in Chapter 4, Industry 4.0 undermines the key comparative advantage of peripheral producers: lower labour costs and labour flexibility. Automation questions the very rationale for relocating labour-intensive business processes to low-cost countries: automated production can be profitably employed near ultimate markets or in headquarters locations (Dachs *et al.* 2017). Moreover, peripheral locations have also competed via the flexibility of labour market regulation (Köllő 2019). However, Industry 4.0 solutions also facilitate production in locations with less flexible labour regulations.[2]

In fact, our case studies do not indicate that the deployment of Industry 4.0 would lead to major structural change in the position of peripheral producers. We observed process upgrading via the use of new technology, but that is rather a continuation of a long-term process: any supplier needs continuously to upgrade production processes to stay competitive, while the rates in supplier contracts typically assume continuous improvements in productivity. However, we did find examples of product, or functional, upgrading, including the allocation of more complex activities extending also, in some cases, to R&D activities. Upgrading via the deployment of new technologies improves the position of affiliates in competing for new product lines, possibly increasing the commitment of the parent company to developing those units. Importantly, however, affiliates enjoyed little autonomy in making decisions about the allocation of such projects. The terms under which they were undertaken were also set by the headquarters. As a result, argues Andrea Szalavetz in Chapter 3, the value chain position of production subsidiaries in peripheral locations does not change even where they experience functional upgrading.

We observed the decentralisation of advanced functions, as anticipated in the optimistic scenario, but their effect on improving the value captured in peripheral sites, and hence securing improvements in incomes, was limited. This can be related to two processes (see also Szalavetz 2017b). First, new technology reduces the strategic importance of delegated functions. Once advanced tasks, such as testing, process development, incremental product development, design and simulation, have been supported by digital technologies, they can be controlled and coordinated from a distance and delegated to subsidiaries as operative functions. Second, as the terms under which the more advanced tasks are undertaken is decided by the headquarters, functional upgrading may not bring higher margins. As affiliates take on additional higher value tasks, parent companies will cover the costs of their execution, such as the salaries of the engineers that need to be hired. The parent companies retain full control of internal prices, so functional upgrading may not increase profitability. The higher value captured thus comes primarily in the form of higher wages for higher skilled staff.

The overall impact of employing new technologies on the position of the analysed companies in the value chain seems to be positive, even if the developmental effects are limited by their peripheral position, namely their dependence on the decisions made in MNC headquarters. In contrast, as argued in Chapter 5, it is the lack of investment in technology that represents a serious threat to lower-tier suppliers. At the same time, however, we observed that Industry 4.0 technologies undermine the key locational advantages of upper-tier producers (the importance of labour costs and flexibility). The position of peripheral producers, as discussed in Chapter 3, is thus arguably becoming more precarious and likely to be tested in the next wave of restructuring.

2. Empirical studies assessing the extent to which there has been a consequent reshoring of activities to higher-wage locations are discussed in Chapter 4.

3. The jobs challenge

The job displacement effects of new technologies have attracted considerable attention. There is now a cottage industry of research that estimates the distribution of the risk of automation across jobs and countries (Frey and Osborne 2017; Arntz *et al.* 2016; Nedelkoska and Quintini 2018; PwC 2018). Estimates of the actual share of jobs that are at risk of automation in individual countries differ, but, as discussed in more detail in Chapters 3 and 8, there is a consensus that industrial employment is particularly susceptible to automation. The operator in production doing routine work thus represents the emblematic occupation at risk of automation. In Europe, CEE countries and Spain rank among those with the highest risk of job losses. This is related to these countries having a higher share of routine jobs (Keister and Lewandowski 2017). Moreover, as discussed above, the rate of automation in these countries is lower than in countries such as Germany that have already made some of the adjustments.

At the same time, the higher productivity achieved through automation is likely to generate demand for labour in non-automated tasks. This may partially (Acemoglu and Restrepo 2019) or even fully (Arntz *et al.* 2016; Dauth *et al.* 2018) offset the negative employment effects of the new technology. However, these positive employment effects take place away from manufacturing, being especially found in the area of business services. While the employment effects of new technologies drive job polarisation at the aggregate level (Autor and Dorn 2009; Goos *et al.* 2014), they also change demand within manufacturing, with IT and electronics knowledge replacing traditional skills profiles (Pfeiffer *et al.* 2016). In this context, it is important to realise that the same technologies can have different effects on labour (or skill) demand, depending on the role of the workplace in the production network (Krzywdzinski 2017). More specifically, when the same process technologies are used, higher skills will be required in factories that are involved in the roll-out and ramping-up of new products and new process technologies – that is, as discussed above, typically in the core locations.

There were no redundancies directly related to the introduction of Industry 4.0 technologies in the companies that we analysed. This may be attributable to our research programme taking place at a time of an upswing in demand in the automotive sector. Indeed, CEE countries actually experienced severe labour shortages. Any labour savings effects were thus seen positively by employee representatives too, as they helped to address labour shortages. Spanish affiliate companies, in turn, were able to relocate displaced workers.

However, we observed that new technologies did have an impact on the skills profile of workers. The increased level of automation and digitalisation implied a demand for new engineering profiles (IT specialisations), a need for programming skills in existing categories of employees (e.g. maintenance workers) and a minimum level of occupational training for new recruits extending to operator positions. The changing skills demand for individual occupations is analysed by Monika Martišková in Chapter 8 on CEE. This shows that education and skill requirements are changing with respect to most positions, requiring a retraining of the existing workforce. At the same time, training policies were developed only in OEMs. Even there, however, a systematic approach aimed at developing skills for all workers whose skill profile was becoming obsolete was missing, while retraining policies were not on the agenda of CEE trade unions. In contrast, as discussed in Chapter 2, trade unions in Germany were able to push for a general policy on re-training, particularly for younger workers with a long-term perspective at the plants. However, even in the OEMs and leading technology providers analysed in the German chapter, re-training mainly involved job rotation, with little re-training provided specifically for Industry 4.0 applications.

At the same time, for some job categories, particularly operators, new technology entailed deskilling. Here, operators became 'machine feeders' monitoring automated processes. What is sometimes described as increased task complexity in fact refers to multi-tasking: workers are put in charge of several machines at once, feeding and monitoring them simultaneously. Work thus becomes less strenuous but rather routine, requiring a lower level of skill. Chapter 8 provides examples of workers whose jobs had been automated who were transferred to routine jobs where they do not need to use the skills that they had previously employed. In this specific case, their wage stayed the same. However, in the longer term, such a transformation is likely to contribute to job polarisation by creating routine, low-paid jobs.

Finally, increased efficiency through the deployment of Industry 4.0 goes hand-in-hand with enhanced monitoring and control over the labour process. Many workers thus lose autonomy, having to follow pre-optimised procedures designed in an automated way and possibly in client companies. Increased work intensification was observed broadly, both in CEE and in southern Europe. Chapter 7, however, analyses the link between work intensification and the deployment of key Industry 4.0 technologies such as ERP. In this chapter, Matteo Gaddi also argues that automatic coordination across the value chain, the core of Industry 4.0, can effectively remove working conditions from the arena of collective negotiation. Gaddi outlines the way in which CGIL/FIOM, an Italian metalworking trade union, has sought to address this via the collective bargaining agenda.

4. Concluding remarks: The Covid-19 challenge

Automation is only one of the major challenges faced by the automotive sector in Europe. The transition towards electromobility, the increasing importance of digital rather than mechanical technology in the final product and prospective changes in the consumer use of automobiles have all put the future of European carmakers in question (Drahokoupil *et al.* 2019; Galgóczi 2019). The economic crisis triggered by the Covid-19 pandemic has added an extreme demand shock that is likely to accelerate restructuring processes, possibly in dramatic ways.

First, the recession will imply a reduction in production capacity in Europe. We have thus now entered the consolidation phase that is discussed in Chapter 3 in the context of peripheral locations only as a looming threat. Tight labour markets were an important contextual factor that both mediated the impact of job-saving technologies and provided an incentive for automation, particularly in CEE. However, finding workers is not likely to be a problem in the next few years anywhere in Europe. At the same time, the crisis may delay investment in digital transformation across value chains. Second, the crisis may accelerate the switch to electric mobility, also because demand stimuli in higher-income countries are likely to be geared towards supporting more sustainable mobility. This, as discussed in Chapters 2 and 4, may reinforce a concentration of production in core locations as well as the opening of new, state-of-the-art production facilities. Finally, we found that Industry 4.0 technologies were deployed in support of the lean, just-in-time model. However, the crisis has highlighted the fragility of such interdependent and geographically-spread systems. A shift towards more resilient production systems may involve reshoring from more remote locations (Van den Bossche *et al.* 2020). However, as argued in Chapter 2, this is not likely to threaten the position of European peripheral locations. In fact, they may witness an opening of new production facilities that fully take advantage of digital transformation.

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The headquarters perspective

Chapter 2
Inside looking out: Digital transformation in the German automobile sector and its effects on the value chain

Pamela Meil

The term Industry 4.0 has been in our discourse for some time now although there is still some confusion about what it means. It is, however, consensus that digital technology, together with other factors, is unleashing a transformation of how things will be produced and new possibilities of what can be produced. One aspect involves a broad array of IT and digital applications aimed at making industrial production more productive or efficient, more networked, increasingly monitored and more automated. Other elements entail potential new product and service innovations, higher quality in production, the generation of more information and analytics, and greater synergy between customers and producers.

Germany, in particular, has placed a high emphasis, backed up by large investments, in Industry 4.0 applications. The hope is to lay a foundation for ongoing competitiveness given the country's still-strong industrial base (compared to other western industrialised economies), especially in the light of the changing production landscape and pressure from emerging economies. Industry 4.0 has become a kind of catch-all phrase, but it does have some characteristic elements: new opportunities are seen in the linking of services and production; there is a stronger connection between pre- and post-production processes; and the roles of the various actors (customers, for example) are being increasingly integrated into the production process (Kagermann *et al.* 2013).

1. A world of global value chains

Another trend characterising the last couple of decades of production in industrial goods, and increasingly also services, is the distribution of activities across global value chains. Initially, low-level tasks and production activities were targeted for outsourcing to lower cost sites (Porter 1985). As time progressed, more and more activities and functions, aided by developments in digital technology, have been outsourced which has created complex networks of production and services (Henderson *et al.* 2002). The motives for externalising activities has varied: costs; access to markets; access to resources; access to labour; pressure from shareholders; pressure to reduce wages at home and push for concessions from local labour forces; and so on (Meil 2019). As a result of developments in global value chains, intermediate production activities have grown extensively (Cattaneo *et al.* 2010), with pieces of the stages of production criss-crossing the globe and making it increasingly difficult to trace the origins of value added creation for a particular product (Linden *et al.* 2011).

Research on global value chains (GVCs) has demonstrated that their growth is dynamic (Gereffi *et al.* 2005, Gereffi and Kaplinsky 2001). The simple outsourcing of a product or process from location A to location B, mainly for reasons of cost reductions, often changes over time as interconnectedness and interdependence grows between the sites. Thus, the simple outsourcing of low-skill tasks for the purposes of cost reduction has long since stopped being an accurate characterisation of global value chains, particularly for industries producing complex products or services such as automobiles. Over time, actors in value chains shift, suppliers change and chains lengthen, altogether creating a complex production network in which supply chains are integrated and interdependently linked (Humphrey and Schmitz 2002).

In this study, the auto industry and its suppliers are a central focus of interest. Complex value chains, developed over a long period of time between dispersed production sites and across supplier networks, play an important role in the automobile sector. At the same time, this sector is one of the main ones in which Industry 4.0 technology applications are being developed, implemented and deployed. The increased potential of automation; the development of 'smart factories' in which logistical systems are digitised, connected and streamlined; the use of sensors in assembly lines; sophisticated person-machine (robot) interactions; artificial intelligence and 'learning' machines; and links between external and internal systems of operation: these are all technologies linked to the term Industry 4.0 and which all have fields of application in the auto industry (Lichtblau *et al.* 2015).

The other contributions in this collection examine developments in new digital transformations in the auto industries of the emerging economies of eastern Europe as well as in Spain and Italy. The former has strong links to western Europe automobile OEMs, and many are outsourced production sites or subsidiaries. There are also subsidiaries of auto manufacturers from other European countries, such as Germany, in Italy and Spain although Italy in particular also continues to ha its own long-standing indigenous auto production and engineering plants.

A central question addressed by these studies is: what effect does, or will, new digital transformations, often subsumed under the rubric Industry 4.0, have on their local or regional sites? As part of OEM value chains, will production and engineering sites be upgraded or downgraded? Will the effects be marginal or lead to noticeable shifts in how and what is produced? And what will be the impact of Industry 4.0 on workforces? Will there be shifts in the division of labour across value chains? Will employees in emerging economies be replaced by automation and their workplaces degraded? Or will the opposite occur: a shift towards more high-skilled tasks and more diverse activities?

Decisions on the future of sites along the value chain ultimately come from OEM headquarters, where strategic decisions are made concerning future investments, site use and capacity as well as the division of labour between sites. This chapter addresses precisely this side of the issue by asking the following question: what strategic orientations do OEMs pursue regarding the implementation and planning of new digital technologies and Industry 4.0 applications at their outsourced sites and subsidiaries?

Many OEMs and their tier one suppliers in the auto industry are located in Germany and this is the case described and analysed here.

2. A note on method

Methodologically, the original approach was to identify companies who were part of the empirical analysis of the other case studies presented in this book. Of those with German owners or headquarters, the design plan was to conduct analyses of matched samples linking expressed central company strategy to conditions at production sites in the countries represented in this collection. This proved impossible to implement due to difficulty of access, in part because of the saturation of Industry 4.0 studies in Germany and the consequential refusal of new requests, and ultimately due to impasses on account of the corona crisis.

In the end, four companies participated in the study: two automobile producers; one high-end automobile supplier which carries out production and facility planning for a broad range of customers; and one highly innovative producer of automation systems. All of the companies have production or engineering development sites dealing with the auto industry in one or more of the countries in southern or eastern Europe represented in this book. Eleven interviews, based on an open-ended questionnaire, were carried out. This information was supplemented with desk research on the companies and issues related to Industry 4.0 and value chains.

3. The cases

3.1 Case 1: EDAG

An engineering service provider to the auto industry with three divisions: one specialising in vehicle engineering; one in the development of production solutions (factory and assembly line planning); and one devoted to electronics development and in-car IT systems. The company has over 8,000 employees and more than twenty sites worldwide, usually connected to the sites of auto manufacturing facilities among others in Italy, Spain, the Czech Republic, Poland and Hungary.

The respondents from production solutions offer a range of services to their auto manufacturing customers that deal with topics surrounding Industry 4.0 applications such as the development toward ‘smart factories’, in which digitalisation and networking for facility, production and logistical planning is conceived and implemented, as well as the potential development of ‘smart assistants’ (for example, sensors and the use of augmented and virtual reality).

3.2 Case 2: Volkswagen

Volkswagen Group is the holding company for twelve auto manufacturers in seven European countries which have about 120 production sites in over thirty countries around the world. The company has some 670,000 employees working in production, services or sales. Production sites can be found in Spain, Italy, Poland, Hungary, Slovakia and Slovenia, most of which began as car brands from those countries and later became part of the VW group. This is important because a certain amount of differentiation and some autonomy exists based on brand identity and history. This is true within Germany as well as outside it.

The respondents for this study came mainly from a newly-established unit within the group: VW Group Components, which emerged out of a long process of converging individual product groups and brands. This unit is the supplier for all of VW's car brands and can also sell to customers outside the group although currently about 95% of its business is within VW. VW Group Components employs 80,000 workers in 61 production sites across 47 countries. It encompasses a broad range of products including seats, undercarriage, gearbox and drivetrain, engines, foundry and e-mobility (batteries for new electric cars, for example).

Auto components production is particularly interesting to study with regard to digitalisation because, while it includes the most labour-intensive parts of manufacturing and assembly, it also contains some of the most automated parts of the production process. Some of the more highly traditional parts of automobile production, and the oldest machines, are found in component production, at the same time increasingly alongside some of the newest and most automated due to the production of electric cars. Electric engines and battery production all fall within the purview of Group Components.

Generally, the idea behind the concentration of components into a centrally-steered group was to bundle the production of certain components at particular sites and to distribute capacity utilisation more efficiently. Obviously, the process of closing down, shifting and concentrating activities was a contentious one. Some respondents portrayed the shift to more modern and digital forms of production as a step-by-step process, particularly because there are production lines and machines that are quite old, but still in operation, and many of these are in Germany. In fact, some of the 'most state-of-the art sites for component production are in eastern Europe simply because they were built more recently.' (VW-5)

3.3 Case 3: BMW

BMW is a premium car brand with about 125,000 employees in auto-related activities worldwide, including the other brands in the group – MINI and Rolls-Royce. There are thirty production plants in 14 countries. Compared to other carmakers, BMW is relatively small and its activities are confined to a relatively low number of countries for actual auto manufacture. Even fewer are involved in higher range activities such as development and engineering. BMW is currently building a new assembly plant in Hungary but, otherwise, auto production is confined to its sites in Germany, China, the US, Britain (due to the takeover of MINI and Rolls-Royce) and Mexico. Unlike VW, BMW outsources considerably to external suppliers for parts and services. It also enters into general contracting agreements with large engineering and design companies to take over pre-production processes for certain projects.

The interviewees from BMW work in prototype development for auto assembly, with expertise in digital transformation processes in pre-series production.

3.4 Case 4: Festo

Festo is well-known in Germany as a highly innovative company specialising in automation technology, including interactive robots and VR and AR applications. An interesting aspect of Festo is that it also has a large business unit specialising in training and consulting and the development of e-learning systems, including an entire set of training modules for Industry 4.0 technologies. The company has over 20,000 employees worldwide and an eighty per cent share of turnover is targeted for research and development activities. Production sites exist in several countries (China and the US have major sites) but in Europe, outside of Germany, only in Hungary, Poland and Belgium. There are also smaller sites for research and development in Hungary and Bulgaria. The export share of what is produced is particularly high: sixty per cent. Most employment is in research and development and in sales (about seventy per cent), with only thirty per cent in production, logistics tasks, assembly and manufacturing.

The interview partner is from the department of solutions technology transfer.

4. Areas investigated in the interviews

The questionnaire used in the study contains three main areas of investigation:

1. Background information on company structure and global presence. The estimated level of Industry 4.0-type applications in the company or the area of the company which the interviewee represents (necessary to limit the focus for very large companies). The estimated growth in importance for specific areas and technological applications of Industry 4.0 for the company or unit, including in a five-year forward-looking timeframe.

2. Company strategy regarding site use and the role of various factors in decisions to outsource or invest in sites. Company strategy for investing in Industry 4.0 applications across the value chain. Determinants or reasons for deciding investments and choosing particular applications. Differences in Industry 4.0 implementation and use between HQ (or home) production sites and remote sites. Opinions on the occurrence of reshoring as a result of Industry 4.0. Opinions on applications that should remain at HQ or the home country and not be outsourced.

3. Effects of Industry 4.0 on workers and working conditions:

   a. increases or decreases in employment

   b. new divisions of labour (also across the value chain)
      — the influence of Industry 4.0 on the use of sites across the value chain and whether this differs by region

   c. effects on worker profiles and qualifications:
      — have new workplaces or tasks been created? Has deskilling or upskilling occurred?
      — the impact of Industry 4.0 on work and tasks: will they become more standardised and simpler, or more complex and demanding? Which kinds of tasks are most affected?
      — training or programmes that are offered for Industry 4.0 applications – by unit and, if applicable, by region

It is obvious that the range of products, processes and services deployed in the company or headquarters unit has an impact on the implementation of Industry 4.0 and its deployment across their value chains. If they are not very far along at home, they are not going to be very far ahead abroad. It is expected that the companies will be at different levels of implementation in different departments and applications. Given this diversity, the goal here is not to convey a definitive portrayal of strategies for future Industry 4.0 developments in a particular company or sector. Rather, it provides a snapshot, based on the estimates of interviewees, of the current conditions and possible business models that German auto producers and tier one suppliers are pursuing for their various sites across the value chain, at home and abroad.

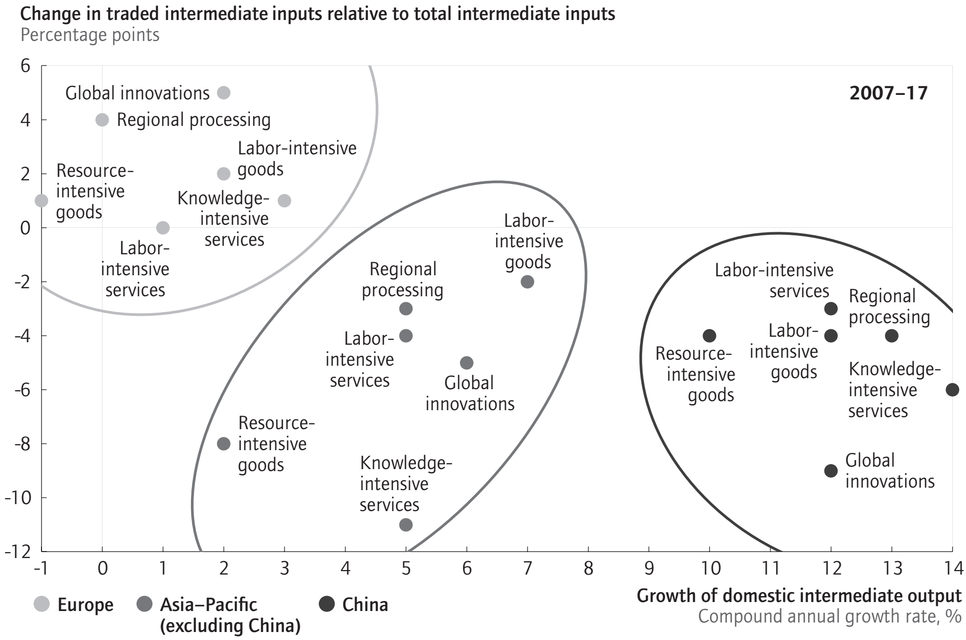
5. The impact of global value chains

Putting developments in the auto industry in context, McKinsey estimates that what it calls 'global innovations' sectors – industries that include automobiles, computers and electronics, and machine-building – have given rise to the most valuable, highly traded and knowledge-intensive of all the value chains involved in the production of goods (MGI 2019). Spending on R&D and intangible assets averages thirty per cent of revenues in 'global innovation' industries, 2-3 times the figure in other value chains (MGI 2019: 2). As Sturgeon (and his colleagues) has shown, a lot of trade in auto manufacturing takes place as intermediate goods (Sturgeon and Memevodic 2011; Sturgeon and van Briesebroek 2011).

Regionalisation, meaning a concentration of value chains in local and regional networks, has been increasing. McKinsey sees this trend as most evident for global innovation value chains, which include the auto industry 'given their need to closely integrate many suppliers for just-in-time sequencing' (MGI 2019: 9). However, a noticeable exception to this trend is central and eastern Europe, which continues to integrate with western Europe as Figure 1 below demonstrates.

It appears that industries in the emerging economies of eastern and central Europe are, in fact, integrating more deeply into the supply chains of OEMs in western Europe. Many countries have joined the production networks of the large western European carmakers (especially Germany).

Figure 1 **China and emerging Asia are building domestic supply chains, while central and eastern Europe continues to integrate with western Europe (reprinted from MGI 2019)**

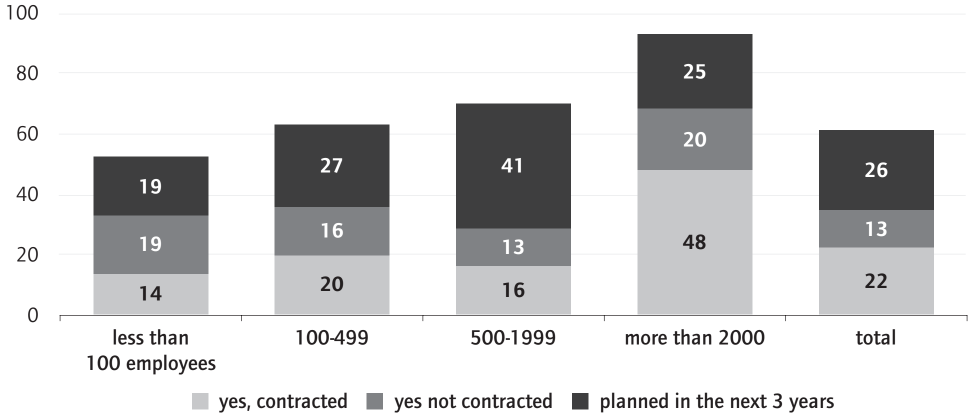


Source: World Input-Output Database; McKinsey Global Institute analysis

6. Findings

Respondents were asked how they understood Industry 4.0 and to assess the relevance for their companies of various applications. Almost all were especially careful in their assessment of the level that their companies had achieved in terms of the implementation of Industry 4.0. Between a choice of beginner, 'on the way' and advanced, most chose 'on the way' to describe where their company stood in the introduction and use of Industry 4.0 technologies. This, in fact, reflects the overall picture that surveys have portrayed on the progress of Industry 4.0 in Germany (see Figure 2) (Kinkel *et al*. 2016; Heidling *et al*. 2019).

Figure 2 **Level of digitalisation in machine-building in Germany, 2016**



Source: Kinkel *et al.* 2016

Explanations for the assessment of 'on the way' revolved around the feeling that only some areas and research topics involving Industry 4.0 were at an advanced stage. In general, however, respondents' perceptions of Industry 4.0 involved highly complex networking and examples of artificial intelligence and algorithm development, albeit that these were still in the early phases of pilot projects at their various sites. Their assessments should therefore be understood as keeping the bar rather high for determining how far along were Industry 4.0 applications in their respective companies. They did not understand the term to mean general uses of digital tools or ongoing shifts towards more automated production.

The implementation of Industry 4.0-type applications was often made initially in the form of pilot projects. This was done either by identifying areas or processes at different sites – also outside Germany – where a particular new tool or application would be especially relevant and then trying to deduce lessons which, eventually, would lead to implementation at other sites. Both BMW and VW had highly similar approaches in this type of initial implementation strategy. One respondent from a supplier who has an overview of several OEMs pointed out that one problem is an abundance of strong pilot projects, 'super islands in some factory, in which Industry 4.0 is practised and demonstrated' (EDAG 1) but that it never really progresses beyond the pilot stage: 'The projects never seem to seep into the regular processes but remain little islands of innovation.' For VW Group Components, in particular, investments to replace older equipment were planned to be carried out incrementally. Although there did seem to be a slight preference for launching innovative pilot projects at German sites – perhaps also because this is where development engineers tend to be situated – the introduction of pilots at other sites was not out of the question. Several times VW's engine plant in Poland was mentioned as being more modern technologically than some plants in Germany and, therefore, a prime location for pilot projects or new investments in technology.

Without actual investment numbers for these specific types of technologies, it is difficult to know precisely how accurate this picture is. Festo conducts most of its state-of-the-art R&D in Germany, but it is a high-end supplier geared to exports. BMW seems to have a number of its pilot programmes in the German headquarters, although some high-end projects specifically related to quality control are being carried out at foreign plants. Meanwhile, VW Group Components has been investing heavily in plants in Chemnitz and Salzgitter; battery research and production, an important future topic for e-mobility, appeared to be prioritised for its German sites. One respondent from VW did raise the possibility – hypothetically – that the production of gas and diesel cars could theoretically be concentrated mainly at older production sites or ones outside Germany, whereas the production of electric cars could be concentrated at newer sites in Germany, at least for European markets. Nonetheless, there was no clearly explicit strategy at any of the companies to invest only in Industry 4.0 technologies at the home country site.

All in all, it seems that future strategies for implementing Industry 4.0 technologies in the cases examined here are still in flux, independent of place. It seems quite evident from the discussions, however, that there is not a clearly articulated strategy to keep external sites at a low technological level either by not investing in their production facilities or by slowly fading them out of the value chain.

Respondents were questioned regarding a list of specific technologies associated with Industry 4.0 and on their view of their relevance for their companies now or in the near future.

- automation
- cyber-physical systems
- business process automation
- digital knowledge transfer
- intelligent solutions (predictive maintenance, workforce analytics)
- artificial intelligence and learning algorithms
- digital networking with external and internal systems.

Looking in detail at these specific applications that are often linked to Industry 4.0 gives a more concrete picture of the use, or intended use, of Industry 4.0 in the overall company strategy, even if companies are still not currently at a very advanced stage of implementation.

All of the respondents indicated that automation would increase and would play a large role in the future of production. It was not always clear, however, if they shared the same exact definition of automation: whether production IT, greater use of robots, etc.

With cyber-physical systems (interactions between worker and robot; and the use of sensors for production monitoring and analytics), the reaction was more mixed. Several interviewees were not familiar with the term or technology while others characterised it as ‘buzzword’. Others did see the potential in cyber-physical systems, depending on what customers (in this case, the OEMs) wanted. Nonetheless, a certain amount of caution or holding back was evident. As one respondent put it, 'I was contacted nearly every week about a great sensor that delivers super measurement data or links to clouds. Like mushrooms popping up after rain. But it must be recognised that such things only work when there is connection to what is actually being produced.' (EDAG 1)

Business process automation and intelligent solutions were also seen as extremely important topics that companies were currently addressing. For several, it also involved efficiency effects in administration and services, not only in production. And for most, the topics dealt with streamlining or even standardising processes. To achieve this, it was necessary to understand the processes, extending right across the value chain, in great detail and this was considered a 'central' challenge for the future. 'If you have an – excuse me – 'shitty' process, and it is digitised, then you have a digitised 'shitty' process.' (VW-4) 'If you can't play the piano, and you buy a really expensive piano, you still can't play the piano.' (EDAG 1) Thus, process optimisation was considered highly relevant, as long as it was understood what processes were being optimised. Predictive maintenance, as a sub-category of intelligent solutions, was already being implemented at many sites. Projects for quality detection using new Industry 4.0 applications and algorithms for machine learning were underway at all of the companies. It is clear as regards these two specific technologies that applications that were easily definable and tightly linked to production were the ones most likely to be deployed.

Knowledge sharing through digital media (Web 2.0, for instance) was not widely practised.

All the companies were, however, interested in using artificial intelligence and algorithms, but they were mainly seen as topics for the future. Moreover, they were all quite careful in utilising the term AI, because it covers a broad range of possibilities and depends on the available data. The auto companies seemed to be targeting AI for the identification or evaluation of mistakes or quality problems in production. Ideas and pilot projects on the subject were in discussion or actually being implemented in both OEMs in this area. One respondent cautioned that, although everyone was talking about AI because it was 'modern', what was being carried out reflected 'minimal' applications. Nonetheless, even this respondent felt that AI would gain importance over time.

With regard to the issue of digital networking both within and outside the organisation, the view was that these types of digital links and networking have existed for a long time, particularly between top suppliers and OEMs. A number of new areas or unsolved issues remain as future challenges to be addressed – among them intellectual property and privacy concerns and also the need for, but difficulties with, the standardisation of systems. For VW Group Components, part of VW Group but nonetheless also a supplier, the goal is a unified system for its internal customer: VW Production. Of course, this includes all sites, even outside Germany, falling within VW Group. The issue seems to be mainly one of achieving transparency, improving logistics and reaching a better just-in-time availability of components. Consequently, new digital tools will be developed and implemented, but whether or not this can be categorised as Industry 4.0 is questionable. Digital networking in Industry 4.0 is further-reaching and involves the links between services and production activities as well as connections with customers.

These types of application seemed less of a concern to respondents than more traditional IT infrastructures and company internal shared databases.

Another of the central issues surrounding digital transformation discussions is the explosion in the data and information being generated. What should be done with this and how should it be used? Where is information collected and analysed, and what are the systems for reporting? For sites down the value chain, and for the empowerment or development of workforces, this becomes a central issue in terms of monitoring, control and autonomy.

The picture that emerges from the interviews is that both local sites and central headquarters are involved in data analysis based on digital data reporting. 'One has to look which data is needed where' (VW-4). At the moment, if plants have their own programme planning or manufacturing control systems, then only local sites need the data. Having said that, there is nonetheless an evident trend that data on the optimisation of production lines will be collected more centrally and then shared. In a positive scenario, in fact expressed by respondents here, the data would be used to improve performance at all the plants. Naturally, the negative scenario is that the data could be used for benchmarking and performance comparison and, theoretically, to substantiate reductions or even closures (Meil *et al.* 2003).

In the strategy department of VW Group Components, for instance, there is a definite plan to move from a decentralised reporting structure delivering reports to headquarters towards a more centralised and standardised structure. Here, the notion is to optimise capacity utilisation at the level of the entire group across all of its sites, and to bundle products and processes ever more efficiently. Consequently, there has been some shift away from local autonomy once held at decentralised units to a more centralised decision-making structure. This development applies to all the units in the value chain, including the German ones. However, in order to achieve a 'real time' reporting flow from the plants to the centre, investments in new types of competencies and technologies are necessary in Germany and beyond. A modern engine plant in Poland is currently seen as the 'gold standard' in which remote reporting via iPads located on the shop floor is available to central monitoring units. On the one hand, this allows increased potential for control and monitoring; on the other, it could have the effect of raising the competency levels of the local workforce.

7. Effects on work and workers

This bring us to the issue of what effect developments in Industry 4.0 have on the organisation of work and working conditions, which is a central focus of the research presented here. Will digital transformation result in a decrease in employment? Will the division of labour shift, leading to a downgrading or upgrading of sites? Will more skilled tasks move to the headquarters or home sites of companies, resulting in remote sites down the value chain becoming external low-skill workbenches?

Given the backgrounds of the interviewees – who come from central headquarters and from departments for strategy, change management and project development, and who do not have detailed knowledge of the organisation of work or the conditions of work at shop floor level – their view is somewhat aggregated and quite abstract. Even in the cases at the level of production described in the other contributions, interviews did not take place with workers themselves. Therefore , we can only portray here a broad picture of possible developments regarding divisions of labour, skills levels and development, general employment trends, etc.

Most respondents expect a decrease in employment in production as a result of increased automation leading to 'efficiencies' in the long run. However, they also predict opportunities in other areas – monitoring, programming, data analysis – to increase. Moreover, most respondents expect a shift in occupational profile, which will affect most areas including production. There are a number of studies on Industry 4.0 which also document such shifts (Hirsch-Kreinsen 2014; Pfeiffer *et al.* 2016; Heidling *et al.* 2019).

Currently, the view is that most of the decreases can be achieved through attrition (retirement, etc.) but this is, of course, mainly with regard to Germany. VW is partially owned by the state of Lower Saxony and there is a ten-year guarantee regarding employment security, particularly regarding the introduction of new digital technologies.

A main issue accompanying digital transformation is that task areas and jobs will be changing, sometimes drastically. This is partly due to digital transformation in the auto sector, but also because of the move to e-mobility which is a major new focus for the carmakers. If this trend continues, many assembly-related jobs will become obsolete.

Previous research has already shown that Industry 4.0 technologies, as well as other changes to the organisation of work, induce a shift in qualification profiles even for skilled workers in production areas (Pfeffer *et al.* 2018; Heidling *et al.* 2019; Meil and Heidling 2010). IT and electronics knowledge are replacing traditional qualification profiles, such as metalworking, machine-building or other specialities in auto-related occupations that were designed for the production of cars based on combustion engines or diesel. With electric motors, subjects which were never considered a part of automobile production, such as chemical engineering, have even become relevant for auto production (VW – 5). The change is, therefore, not only about low or high skills, but also a massive shift in the competence mix of the workforce. This affects all sites, although perhaps at different speeds and with different emphases.

Interestingly, there seems to be an inclination at the central divisions and strategy levels to think very much in terms of processes rather than people. Consequently, the overwhelming focus is on getting the technology, and especially the process, right. The other things – work organisation or the composition of the workforce – are expected to adapt or be adapted to meet the new demands. Given that the line of communication at these levels is mainly with management or engineers, this view is not so surprising. Certainly, getting processes right across a complex value chain are crucial. Nonetheless, this fairly typical planning orientation – first the technology, followed by competencies and the organisation of work – has been the *modus operandi* in most development waves and this almost always leads to problems in implementation (Böhle 1998; Böhle *et al.* 2002).

The general tenor of the interviews is that some jobs will be lost as a result of Industry 4.0 but others will be gained. There has been some thought about how to enact the shift, particularly in light of employment protection regulations in Germany and given that trade unions are a strong factor in this particular industry. The general concept seems to be of a long-term 're-training' by having younger workforces – those with a long-term perspective at the plants – rotate through various workstations for stints of several months. It is unclear if similar arrangements are being offered across all sites and countries, although itis quite clear that such programmes are not targeted for older workforces.

It is evident that, other than recruitment and job rotation strategies, there appeared to be little training taking place specifically for Industry 4.0 applications at any of the sites in any of the cases.

What will happen to work as a result of the introduction of Industry 4.0? With regard to effects on work tasks and content, we asked what future developments could be expected. These findings would then give us additional information on whether work might be deskilled, and thus easier to automate, or what kinds of reskilling could be expected and what types of workers would be sought. In line with questionnaires from the other case studies presented in this book, we asked if activities would become increasingly standardised simpler, or more demanding and complex.

Interestingly, most respondents understood standardisation as compatibility and not as a characteristic of a task or activity. Thus, they predicted an increase in standardisation, but mainly regarding product platforms or systems integration rather than of the tasks or activities being carried out by workers. Some, however, suggested that tasks would become simpler in terms of being based on systems and architectures that would make operating systems easier to use, also as regards shop floor operators, by using digital technology interfaces. Some loss of competence in certain activities could also be expected through the deployment of artificial intelligence. Areas mentioned were evaluation and quality assurance, which currently depended on high levels of worker experience but which were tasks that could potentially be replaced by artificial intelligence and machine learning. Otherwise, respondents tended to believe that many aspects of working in digital networked environments would become more demanding and interesting. This was the case because the activities would become more diverse and less repetitive and would include new topics and areas of expertise.

8. Impacts on the value chain

As one interviewee put it, 'the automobile industry is one of the most globally networked and logistically optimised industries' (VW-5). Because of this, all the respondents felt that, when it came to strategies for introducing digital technologies abroad, it was necessary to include all the actors in order for the system to work the way it should. This not only goes for the OEMs but the suppliers as well. Thus, the idea is to link not only the various sites and tier one suppliers, as is the case now, but in the future also the tier two and even tier three suppliers. Only in this way can the advantages of Industry 4.0 technologies be optimised. EDAG is one of those tier one suppliers, but it also carries out work as a general contractor for OEMs. The EDAG respondent pointed out that everyone along the chain must have the same tools and methods. 'To put it bluntly, I can't have my colleagues in India use a drawing board while we work with CATIA V5 [an engineering software program].' The main argument why digital transformation will tend to upgrade the individual parts of the value chain is that the desired increases in efficiency, transparency, monitoring and control systems cannot be achieved without an overall coordination between all of the actors, including suppliers and remote sites. It is an economically-driven logic, not one based on empowerment or a strategy for upgrading.

What implications the resultant upgrading has for the organisation of work, the division of labour and workers' competencies and qualifications at individual sites seems to be a secondary consideration. The local sites have to adapt because the requirements come from the headquarters to deploy certain technologies and achieve targets.

9. Reshoring?

There is a fair amount of hype in the current discourse in Germany about the potential for reshoring, in particular in connection with the increased deployment of Industry 4.0 applications. The argument is that new investments in digital technologies that bring high levels of efficiency and capital utilisation, together with synergy effects concerning production, services and customers, makes reshoring increasingly attractive (Strange and Zucchella 2017).

Quite frankly, the evidence for this position is not particularly convincing. For one thing, the levels of Industry 4.0 deployment in Germany are still so marginal that it is hard to mount arguments that it is leading to reshoring. Certainly, there has always been a certain amount of reshoring by companies which underestimated the transaction costs and the long-term investments involved in outsourcing, especially for complex products and processes. Levels of reshoring have actually remained amazingly constant over the last decade (Eurofound 2016). Nevertheless, the extremely high levels of outsourcing characterising the latter part of the 20th century have slowed down, partly as a result of saturation levels having been reached and partly as a result of the post 2008-2009 financial crisis.

Companies which have a longer track record of outsourcing, however, a category to which carmakers belong, have complex value chains which are part of a dynamic process of growth and change. Once offshoring or outsourcing has taken place, various forms of upgrading usually occur: products, processes, functions, shifting to new sectors or shifts in complete value chains – all of which have labour and capital dimensions (Gereffi *et al.* 2011; Gereffi and Kaplinsky 2001). In the development of value chain integration, the movement tends to be from lower to higher level activities within sectors, for instance to high value added and more knowledge-intensive activities (Meil 2019). The automobile sector is, naturally, part of the industrial group which has high levels of knowledge-intensity (MGI 2019).

There are basically three scenarios that can be hypothesised as outcomes for offshored or outsourced sites as a result of the introduction of Industry 4.0 digital applications:

1. The central sites invest in new technologies at home and thereby pursue a reshoring strategy. This would mainly result in the downsizing or closure of offshored or outsourced sites over time

2. Value chains undergo a shift – this can occur in two directions:
   — an upgrading of the site through investment and the introduction of new digital technologies
   — a downgrading of the site through a lack of investment in new digital technologies, thereby reducing it to carrying out low-level tasks with low levels of skill. The site would service mainly as a cost-cutting destination, based on standardised products

3. There is no clearly discernible change in the relationship between offshored or outsourced sites and the headquarters, and roles in the value chain are not affected by Industry 4.0 technological transformation.

The vast majority of respondents in this sample did not believe that digital transformation would lead to an increase in reshoring. The consensus was that value chains across sites were already highly integrated and interconnected and that new investments in Industry 4.0 were unlikely to change this.

As we have seen, some respondents here did mention the possibility that companies could decide to concentrate their 'old' technology or products, i.e. diesel motors or cars using the combustion engine, in sites outside Germany while building plants for new products and applications at home. The opinion was that, given core competencies and quality considerations, it made sense to keep important processes and products for the future in Germany. Some companies, such as Festo in this sample, concentrate on high-end products and in any case manufacture largely within Germany. Indeed, they expect that, with such new technologies as 3D printing, specialised niche production could be carried out more easily in domestic plants.

Festo's position on reshoring was most definitely a minority position among respondents in this sample, however. Among the rest, a common position did exist that, for new and proprietary products, it might be worthwhile considering what could be produced at home rather than be externalised. On the other hand, it was considered highly unlikely that production that had already been outsourced would be brought back, nor that not investing in the digital transformation of existing remote sites across the value chain was a realistic option. In general, the strategy of differentiating between old and new products in terms of site use does not appear to be particularly clear-cut at present. It would be worthwhile considering which areas of Europe might be most susceptible to strategies geared to differentiating between old products and new ones.

10. Concluding remarks

OEMs and tier one system suppliers who would, presumably, be the companies dispersing new digital and Industry 4.0 applications across their value chains are still in the process of undergoing transformations themselves. Certainly, some applications, particularly in the automobile industry, are quite advanced: those involving logistics, ERP systems, automation with standard robots and some shop floor digital interactive software. Others are currently being introduced in the form of pilot projects. But for now, it is hard to discern any clear trend in terms of shifts in the division of labour or jarring changes in the organisation of work.

It does seem clear, however, that change facilitated by digital tools will continue and that it will have effects as regards job losses and job gains, shifts in occupational and competence profiles and, possibly, adjustments in the position and role of various sites across the value chain. For production in the carmaking industry, it does not appear that there will be major differences among sites further down the chain when re-tooling for more digital processes and networking of systems. It does not make sense to have sites at quite different stages of development. However, it is particularly in assembly, where the lowest-skilled parts of production exist, that the greatest moves toward automation, and accompanying employment loss, will take place. Although there might be some time lag in re-tooling between sites – old or new, outsourced or at home – the planning is for it to occur at all sites along the chain. This does not necessarily mean that the situation for all sites along the chain will be the same. In times of recession, as in the current corona crisis, employment reduction will tend to occur in places where the conditions for labour are more precarious. That is, those with less labour protection and union organisation.

In terms of decision-making, strategy, steering, etc. there are also differences across the chain. The companies examined here have their design, development and innovation management facilities mainly at home. It is at the headquarters where high-end developments in digital transformation take place and which ultimately decides what technologies get developed and where they are implemented. It is largely left to local sites to find ways to adapt to these changes, for instance, in the preparation of their workforces. Although local units have a say in capacity utilisation and other control issues relevant for their plants, decision-making is generally becoming more centrally-managed at company headquarters. This is especially evident for VW which, formerly, had a large network of different brands with fair amounts of autonomy to operate in their particular areas. Now, there is a push by Production or Group Components to streamline the use of sites. In all the cases described here, this has certainly not meant a phasing-out of sites located outside the home country; at least, not up to now. In fact, there are sites in eastern Europe that, although small, are some of the most modern in the company portfolio.

Ultimately, it does seem that there will be a shift in value chains with some upgrading occurring for those sites that survive the new demands. However, it appears that there will also be an increase in the monitoring and centralised analysis of data and that the design, engineering and development tasks linked to Industry 4.0 will remain, mostly, at home.

Sars – Cov-2

It would be remiss not to try to consider what effects the pandemic – the most significant event of our time – might have on the issues discussed here.

Some of the interviews and the writing of this chapter took place during the corona crisis. It should not be expected that this crisis would have a particularly strong impact on the results of this study but it was, nonetheless, an all-embracing topic on the minds of participants. Firstly, a great deal of their work, as well as some of the empirical work carried out for this project, was moved to the digital world. Many respondents felt this would have a lasting impact on how work is carried out and that much more would now be done virtually. It also made it all the clearer how inextricably integrated and interconnected were their supply and production chains within the global world of the automobile sector. This was not necessarily a soothing thought. They did not feel this would necessarily change post-corona, but it did bring to the forefront the interdependence and fragility of systems. Thus, there were some new considerations of whether proprietary systems or technologies that were of particular significance for the company's future should, perhaps, be kept closer to home. However, these cautionary thoughts seemed to apply less to Europe and rather more for sites further afield.

Nonetheless, the major recession which is confronting the global economy, and which is hitting the automobile sector as much as any other, is most likely to lead to job loss and site closure. It is easier to cut employment in countries in which labour protection and job regulation are low, and additionally in which the role of local markets is not so high. This could be bad news for the sites of German carmakers in the emerging economies of eastern Europe. It may be temporary, but it could well lead to a delay in shifts toward digital transformation across the value chains.

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Digital transformations in factory economies

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

Andrea Szalavetz

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.

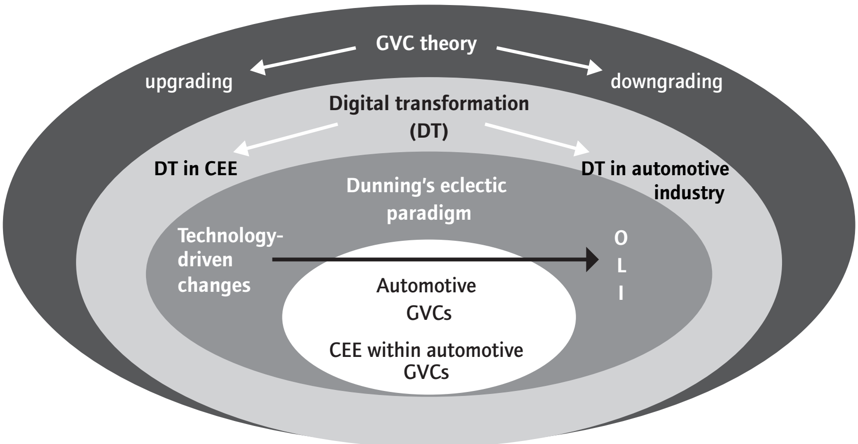
The automotive industry, dominated by foreign-controlled, export-oriented manufacturing units: subsidiaries of global original equipment manufacturers and their global suppliers (Pavlínek 2017), was selected as the specific context for the research since this industry is a forerunner, also in central 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

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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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Chapter 4
Digitalisation and the role of MNC subsidiaries in the Spanish automotive industry

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1. Introduction

There are some earlier references, but it is common to attribute the term 'Industry 4.0' to the report by Kagermann *et al*. (2013) (see also Kagermann 2015), which was drawn up to make a diagnosis of German industry and its ability to cope with the new technological scenario of digitalisation, or digital transformation, as well as of the reforms required to assimilate it in an optimal way. The name comes from the estimate by the authors of the report that this digital transformation is, in fact, the beginning of the fourth industrial revolution, characterised by the development and introduction of cyber-physical systems (CPS). These are defined as: 'Systems with embedded software (as part of devices, buildings, means of transport, transport routes, production systems, medical processes, logistic processes, coordination processes and management processes) which: directly record physical data using sensors and affect physical processes using actuators; evaluate and save recorded data, and actively or reactively interact both with the physical and digital world; are connected with one another and in global networks via digital communication facilities (wireless and/or wired, local and/or global); use globally available data and services; and have a series of dedicated, multimodal human-machine interfaces.' (Acatech 2011: 15)

The term 'Industry 4.0' has been successful and is already widely used, although it has met with reticence in the academic world. For example, Valenduc (2018) and Valenduc and Vendramin (2017) argue, on the basis of the concept of the techno-economic paradigm (cf. Perez 2010), that it is not really a new paradigm but rather the transition between the installation and deployment phase of what, according to Perez (2010), would be the fifth paradigm since the industrial revolution. This began around 1973 and is based on the microprocessor, information and communications technologies (ICT) and biotechnology. In an earlier document from 2012, the European Commission, following (for example) Rifkin (2012), was still referring to the 'third industrial revolution' (European Commission 2012: 7). In fact, in the case of Industry 4.0, it is not so much a question of new technologies as of their application to the production process in search of greater flexibility, efficiency and competitiveness, so such objections are not without significance.

In exposing the scenario behind Industry 4.0, ideas and arguments may be repeated, but the most familiar in the analysis of organisational and technological changes is that from the 1980s which led from vertically-integrated Fordism to the model known – among other denominations – as lean production. For example, in Roland Berger (2016: 5) one can read: 'It will also allow… a switch from push-production – make and build up inventory – to pull-production – make to order.' Aoki (1990), Coriat (1990) and Womack *et al.* (1990) are three studies from that time that insist on the idea of switching from push-production to pull-production, with the model of the Japanese automotive industry as an example. Dorrenbacher *et al.* (2018) also refer to a renewed impact of the principles of lean production on European MNCs (multinational corporations).

Other names referring to the same process are digital transformation, digitalisation, smart industries or advanced manufacturing, which is the one most used in the United States (PCAST 2011). Although there are subtle differences in concepts, particularly between the German and the American visions, what these different names share is an emphasis on the development of cyber-physical systems and the use of large amounts of information, both for the operation of intelligent machines in the production process and for quality improvement, predictive maintenance or adaptation to the needs of specific customers (customisation and mass customisation). Taking into account the above-mentioned nuances, in this work, for convenience, we will use the term 'Industry 4.0'.

The adoption of technologies that could be encompassed by Industry 4.0 is a recent phenomenon that is expected to have significant economic consequences, both quantitative and qualitative as regards the demand for labour and possessing a likely impact concerning the location of production activities. In this sense, the available works that anticipate such effects are generic, with estimates for a country as a whole and even for the global economy (see, for example, Acemoglu and Restrepo 2019; McKinsey 2017; PwC 2018; Roland Berger 2016; WEF 2016). The main result of these kinds of works is a set of estimates of the possible macroeconomic effects of the spread of Industry 4.0, which leaves open a whole set of questions concerning the qualitative characteristics of this process. What is the rate of introduction of the different technologies in Industry 4.0? Do MNCs have a strategy for adopting these new technologies in their different assembly plants? What effects is the introduction of Industry 4.0 having on employment in assembly plants? What are the main advantages of the introduction of Industry 4.0 in the opinion of those agents directly involved?

This chapter aims to provide answers to these questions by obtaining direct information from qualitative interviews with representatives of a number of automotive assembly plants located in Spain. Plants in the automotive sector have added interest, since this sector has been indicated as one of the most susceptible to the introduction of Industry 4.0 technologies and, in addition, MNCs in this sector could be taken as a model for the possible effects of the expansion of Industry 4.0 on the location of value chains (Dachs *et al.* 2019b; Deloitte 2020). In contrast to generic trends, the field work and its results offer a more realistic picture of the degree of implementation of Industry 4.0 in the Spanish automotive sector, allowing an understanding of the qualitative aspects related to intra-company dynamics and competitive pressure.

The information obtained through the field work identifies a higher level of integration of the production process in a company's enterprise resource planning (ERP) system, as the main technology being implemented. Automation is increasing, but no structural change seems to be detected. Besides, initiative on the introduction of Industry 4.0 in

MNCs corresponds to the level of the plant and is highly dependent on the motivation of the personnel directly involved: the introduction of Industry 4.0 technologies is being carried out with the close collaboration of local agents. On the other hand, the changes indicated have not, for the moment, led to appreciable cuts in employment, although there are indications of reassignments of workers to new tasks as well as a demand for new profiles and new skills in certain jobs.

The chapter is organised thus. Following this general introduction, we detail in section two the literature on the Industry 4.0 process itself, as well as its impact on employment, global production and the Spanish automotive industry. We set out our approach to the field work in section three, while section four analyses our results as regards the chronology of Industry 4.0, the process of its introduction and its main advantages, the impact on working conditions and employment, and its effects as regards the positions of plants within MNC value chains. We end in section five by drawing some conclusions.

2. Literature Review

2.1 Industry 4.0: technological delimitation

In both the United States and Germany, the starting point is the assumption of the historical strength of the automotive industry, its weight in R&D activity or in the employment of highly-skilled workers, as well as the decline experienced in recent decades (PCAST 2011, 2014; Kagermann *et al*. 2013). The latter has different characteristics in the two countries, although it is much softer in the German case. Thus, manufacturing employment in the United States has gone, between 2000 and 2017, from 14 per cent to ten per cent of total employment and in Germany from 20 per cent to 17 per cent; as for gross value added, in the United States this has dropped from 16 per cent to 12 per cent while in Germany it has remained stable at 23 per cent, although in 1991 it was up at 27 per cent (data from the OECD and Statistisches Bundesamt). There is concern about halting this decline and the fear that not only industrial value added, but also pre- and post-production services, will end up leaving the country.

The lists of technologies included in the concept of Industry 4.0 are highly similar. Strange and Zucchella (2017) group them into four categories: the Internet of Things; big data analytics; robotics; and additive manufacturing (3D printing). Meanwhile, CB Insights (2019) distinguishes 14 technologies grouped into four categories: necessary (Internet of Things, industrial sensors, robots/collaborative robots (or ‘cobots’) and predictive analytics); experimental (edge computing, industrial drones, personalised manufacturing, augmented reality and virtual reality, wearables and industrial blockchain); threatening (machine-vision and machines-as-a-service); and transitory (3D printing and data interoperability).

The world of Industry 4.0 is one of optimisation and flexibility. Central to this is information, collected and analysed in real time and aimed at connecting all elements of the factory, performing simulations and obtaining models through virtualisation, as well as the continuous exploration of new services for potential customers. Information management must translate into the optimisation of decision-making and, therefore, improvements in the efficiency of resource use (Kagermann *et al*. 2013). A large part of these activities is related to services associated with the development or end-consumer phases of the relationship and form part of the so-called 'servitisation' of the industry (Vandermerwe and Rada 1988; Raddats and Kowalkowski 2014; Raddats *et al*. 2019).

Industry 4.0 comprises a transversal technology – that is, it is applicable to a multitude of productive sectors – although its adoption can be expected to be gradual, with different rhythms both sectoral and corporate, in a process in which the organisational culture of the company and the mentality of managers themselves can be decisive.

Given that our work on which this chapter draws focuses on the production process, we have used in our interviews with companies and social agents the following breakdown of those Industry 4.0 technologies which are directly related to production:

— logistics solutions for inventory and warehouse management;
— self-guided vehicles (AGVs);
— data extraction systems (CBS): sensors and real-time control;
— augmented reality systems;
— virtual reality systems;
— automation of management procedures: order management, reports, production programming, remote maintenance, etc.;
— cobots;
— 3D printing;
— functional printing (printed electronics);
— knowledge and information sharing systems (between workers or with suppliers);
— intelligent systems: support for decision-making in production planning, process optimisation and predictive maintenance;
— industrial drones;
— artificial intelligence and neural networks.

The ultimate goal is improved profitability, which arises both from value creation and improved asset utilisation rates as well as reduced labour costs (Roland Berger 2016; BCG 2015). There is a very strong emphasis on planning and logistics, especially supply and inventory management, but also on reducing maintenance time by incorporating preventive maintenance.

2.2 Industry 4.0 and employment

One of the most controversial aspects of the implementation of Industry 4.0 is its impact on employment, although it should be clarified that most of the work does not concern Industry 4.0 as such but automation. A first estimate, seeking to capture an equivalent phenomenon and which had a considerable impact, was that of Frey and Osborne, published as a working paper in 2013 and as an article in 2017, which estimated that 47 per cent of jobs in the United States were at a high risk (i.e. over 70 per cent) of being automated whereas only 33 per cent of jobs had a less than 30 per cent risk of being automated (see Frey and Osborne 2013, 2017). Their estimate was based on an approach which focused on occupations.

Arntz *et al.* (2016), using a contrasting individual job-oriented approach as a point of reference, estimate for a sample of 21 OECD countries that around ten per cent of jobs are likely to be made redundant over the next two decades as a result of technological progress, although they note that there are significant differences among them (see also Arnold *et al.* (2018), who argue that this impact does not have to translate into a similar increase in unemployment and that, in the long-term, the overall effect on employment will be positive). For the United States, the figure is nine per cent.

For their part, Nedelkoska and Quintini (2018), applying the criteria of Arntz *et al.* (2016) to data from 32 countries and across a wider group of workers, estimate that 14 per cent of jobs are at high risk of automation (i.e. with a probability of automation greater than 70 per cent), while another 32 per cent would have a probability between 50 and 70 per cent. Countries that, according to Nedelkoska and Quintini (2018), present a lower risk of automation to the median worker are located in northern Europe (Norway, Finland, UK, Sweden, Netherlands and Denmark), northern America (United States and Canada) and New Zealand. In contrast, the countries with the highest risk are located in southern and eastern Europe (Slovak Republic, Lithuania, Greece and Spain), in addition to Germany and Japan.

Frey and Osborne (2017: 265) find that 'A substantial share of employment in services, sales and construction occupations exhibit high probabilities of computerization,' although Nedelkoska and Quintini (2018) had concluded that automation mainly affects jobs in industry and agriculture, with few service industries being at a high risk of automation. Furthermore, the latter come to the *a priori* surprising conclusion that up to 71 per cent of the variation between countries may be explained by intra-sectoral differences (differences in the organisation of production within the same sector) while only up to 29 per cent of it may be accounted for by inter-sectoral ones (the industry mix).

PwC (2018) provide estimates on the percentage of jobs at risk due to automation for 28 countries, ranging from 22 per cent in Korea to 44 per cent in Slovakia. The countries most affected are in eastern Europe: in addition to Slovakia, they are Slovenia, Lithuania and the Czech Republic. However, it obtains a negative relationship between job automation risk and the density of industrial robots (industrial robots per 10,000 employees in manufacturing industry), by which we can understand that some countries (such as Korea, Singapore, Japan or Germany) present a lower risk because they have already made part of the adjustment.

The perception that the impact is distributed by activity, and that the net balance is positive, is widespread. In addition to the work already mentioned by Arnold *et al.* (2018), BCG (2015) forecasts a net increase in employment, at least in Germany. Thus, it estimates that Industry 4.0 could increase employment between 2015 and 2025 by 350,000 (five per cent), resulting from the creation of 960,000 new jobs and the disappearance of 610,000, based on generating additional economic growth annually of one per cent. The reduction in employment will take place in factories, mainly due to the introduction of robots. This is a conclusion which is also supported by Roland Berger (2016) which, in a simulation for an automotive supplier, obtains the result of a reduction of almost half of employment (45 per cent) although it adds: ‘People are still at the heart of the system’ (Roland Berger 2016: 5).

Meanwhile, McKinsey (2017) estimates that, in a midpoint adoption scenario, automation could replace, depending on the country, between nine per cent (India) and 26 per cent (Japan) of employment (from a set of reference countries that also includes Mexico, China, the United States and Germany). It does not make estimates of the net balance but, from historical analysis, concludes that technical change generates net employment.

The way in which automation affects employment is related to its differing impact on occupations and skill levels. It is generally accepted that automation particularly affects tasks that require a lower level of skills, especially in production. Thus, Nedelkoska and Quintini find: ‘A rather monotonic decrease in the risk of automation as a function of skill level’ (2018: 50). Dauth *et al.* (2018), for Germany, and Acemoglu and Restrepo (2017), studying the specific case of robots, come to a similar conclusion.

Acemoglu and Restrepo (2019) went on to establish a theoretical model to analyse the ways in which automation affects employment. The net impact of automation in a sector and on added employment is the result of two effects that pull in opposite directions. First, there is a productivity effect, since automation increases added value and generates demand for labour in non-automated tasks, which therefore acts in a positive fashion. Second, however, there is a displacement effect which arises because automation displaces work from tasks previously assigned and tends therefore to reduce employment. To the extent that it cannot be ensured that the productivity effect is greater than the displacement effect, there is no guarantee that the final impact on employment will be positive. Furthermore, ‘Different technologies are accompanied by productivity effects of varying magnitudes and hence we cannot assume that one set of automation technologies will impact labour demand in the same way as others’ (Acemoglu and Restrepo 2019: 11). In their view, this could explain the differences observed, for example between Germany and the United States, following the introduction of industrial robots.

The case of industrial robots has received specific attention and there is a consensus that they contribute to reducing employment in the industries in which they have been installed. However, differences arise when appreciating the overall effect on the economy as a whole. In their analysis of the implementation of robots in the United States, Acemoglu and Restrepo (2017) estimate that, relative to a local labour market (commuting zone) with no robots, an increase of one robot per thousand workers leads to a reduction in the employment to population ratio by 0.37 percentage points and in average wages by 0.73 percentage points. This led them to an estimate of total job losses for the country as a whole between 1990 and 2007 of 360,000-670,000. The negative effects are concentrated in manufacturing, while finance, the public sector and non-robotised manufacturing show positive effects. Negative (or, at best, null) effects are distributed across all occupations (except managers) and all education levels. Those with the lowest wages are most affected, which results in increased wage inequality.

Dauth *et al.* (2018) analyse the implementation of robots in Germany, concluding similarly to Acemoglu & Restrepo (2017) in terms of the existence of job losses in the industries where they have been installed as well as in terms of their impact on wages and in the widening of the wage gap. However, they also find that the losses in manufacturing are almost offset by gains in other activities, especially business services. They estimate that one robot per thousand workers replaces 2.11 jobs in industry (manufacturing jobs) while generating two jobs in services (the aggregate effect on employment relative to the population will thus be -0.018 percentage points). In other words, robots change the composition of employment but not its aggregate level. In addition, they conclude that part of the adjustment takes place within the factories themselves, with the outcome of job losses being reflected in fewer jobs for young people.

The relatively greater damage to wages resulting from automation seems to exist in contradiction to the trend of the polarisation of employment into high and low skill areas, to the detriment of those in the middle. Representative works on this position are those of Autor and Dorn (2009) and Goos *et al.* (2009, 2014). We will not go into the content of these contributions here, although we should point out that such a result is, perhaps, greatly influenced by the identification that is made between salaries and skill level, such that low skill is attributed to low salaries and high skills to high salaries. By way of hypothesis, it could be ventured that the relative reduction in industrial employment and the expansion of lower-paid, but not necessarily lower-skilled, service activities (for example, many care services and feminised occupations), as well as the trend itself towards lower wages in industry, may have something to do with this wage depression at the average level.

2.3 Industry 4.0 and the global organisation of production

It has not been explicitly considered in the empirical analysis, but there is one remaining aspect that seems relevant to consider here: the impact that Industry 4.0 technologies may have on the organisation of production on a global scale and, particularly, that of the automotive industry. Globalisation is associated with the fragmentation and geographical dispersion of production, facilitated by information and communications technologies (Dicken 2015). The result is the configuration of so-called ‘global production networks’ (GPNs: Yeung and Coe 2015), or ‘global value chains’ (GVCs: Gereffi *et al.* 2005; Gereffi and Fernandez-Stark 2016). This has occurred within the process of extending the operations of MNCs and their establishment of complex networks of productive and organisational relationships with their suppliers, both internal and external. However, this offshoring process may be coming to an end (De Backer and Flaig 2017), with the detection of movements of activities, either of the company itself or of its suppliers, to the company’s country of origin. This process began as reshoring, although today the term ‘backshoring’ is widely used. Backshoring is not necessarily the return of a previously-offshored activity since a company may have been able to expand by building new production capacity or acquiring companies in the destination country (Dachs *et al.* 2019a).

Backshoring has attracted much interest in recent years and studies are beginning to proliferate which try to quantify it and to establish its impact, although general theoretical models are still to be developed and the vast majority of empirical analyses are based on case studies. Barbieri *et al.* (2018) carry out an exhaustive review of the literature on reshoring, with a base of 57 documents (53 articles and four book chapters). Two papers arising from the analysis of a large sample of companies taken from the 2015 European Manufacturing Survey (EMS) have been contributed by Dachs *et al.* (2019a, 2019b).

It is not easy to quantify the extent of the phenomenon. Heikkilä *et al.* (2018), in a study of Finnish companies, find that 13 per cent of companies had moved production to Finland between 2010 and 2015 (26 per cent had moved activities outside the country in the same period, since backshoring and offshoring coexist and the latter remains even more significant). Johansson and Olhager (2018), in their analysis of the Swedish case of backshoring, estimate the percentage of companies at 27 per cent between 2010 and 2015. These are high percentages, far removed from the 4.3 per cent obtained by Dachs *et al.* (2019a). However, all three studies are in agreement on the more intense impact of backshoring on high-tech activities, as well as on the reasons cited for engaging in it. The latter can be summarised as the search for greater flexibility and quality, an under-utilised capacity problem and aspects related to logistics, such as transport and coordination.

This leads us directly to the relationship that may exist between Industry 4.0 technologies and backshoring since, as we have seen, Industry 4.0 facilitates increased flexibility, adaptability, improved coordination and adaptation to specific customer requirements. We should also add reductions in costs, particularly labour costs, as well as the reduction in the share of labour in income (Dauth *et al.* 2018; Acemoglu and Restrepo 2019) as a result of the change in the capital/labour ratio. Therefore, Industry 4.0 is directly related to the objectives being pursued under backshoring, while it also makes it possible to sidestep one of the most powerful reasons for offshoring, which is savings in labour costs (Di Mauro *et al.* 2018), as well as the lack of flexibility in labour rules and laws (Heikkilä *et al.* 2018). Dachs *et al.* state: 'The modernization and innovation of these home plants by implementing advanced production technologies and accelerating the digital integration of value adding processes (Industry 4.0) might play an important role, as economies of scale and high capacity utilization become all the more important in such high-tech and high-invest lead plants' (Dachs *et al.* 2019a: 7).

In their second paper, devoted specifically to the relationship between backshoring and Industry 4.0, Dachs *et al.* (2019b) find a positive and significant relationship between backshoring and investment in Industry 4.0 technology. They estimate that Industry 4.0 brings two benefits to companies: firstly, increased productivity and capacity utilisation, which translates into lower production costs; and, secondly, greater flexibility and quality, which enables customised production with very low marginal costs.

In the case of the automotive industry, one more element could act, in addition to investment in Industry 4.0, to feed backshoring: the switch to electric vehicles and possible changes in trends in the demand for cars, the types of vehicle ownership and in mobility patterns all imply far-reaching changes in the industry that may reinforce the concentration of activity in companies' countries of origin.

2.4 Spanish automotive industry and Industry 4.0

The Spanish automotive industry is very significant, both for the country's economy and in comparative terms with other EU countries. Total employment in the industry (NACE C29) was 158,000 people in 2017, 8.2 per cent of the country's manufacturing sector (data from the National Statistics Institute, INE). It generated ten per cent of manufacturing value added (€11.3bn) and is also a relevant destination for investment since, in 2017, it accounted for 15.8 per cent of all manufacturing investment.

However, the overall impact of the automotive industry on the Spanish economy (including related services and gross fixed capital formation) is much larger. According to data from ANFAC (Spanish Association of Automobile and Truck Manufacturers), GDP related to the automotive industry represents about 8.6 per cent of Spanish GDP.

Twelve assembly plants are located in Spain (there are actually two Nissan plants, the one in Ávila being dedicated, however, to the manufacture of components for Renault); one plant is owned by Ford while eleven are owned by European manufacturers:

— Ford: Valencia;
— Iveco: Madrid, Valladolid;
— Mercedes-Benz: Vitoria;
— Nissan: Barcelona (Nissan announced the intention to close this plant in May 2020);
— PSA: Madrid, Vigo, Zaragoza;
— Renault: Palencia, Valladolid;
— Volkswagen Group: Barcelona (Seat), Pamplona (Volkswagen).

There have been no greenfield investments in plants assembling vehicles in Spain for thirty years (Aláez-Aller *et al.* 2015). In addition, SERNAUTO (Spanish Association of Equipment and Component Manufacturers) estimates that there are more than 1,000 companies dedicated to the manufacture of components (equipment and spare parts), belonging to 720 groups. Consequently, it is only possible to find companies that have Spanish capital at the level of component manufacturers.

The location of operations in the automotive value chain in Europe has been characterised by two hierarchical structures (Lung 2007; Pavlínek 2015): one for assembly (with high-end models being assembled mainly in core countries – France and Germany – while the peripheral states of Europe have become specialised in the assembly of lesser vehicles); and the other based on functions (R&D has been concentrated in the core regions of the EU which have become the home for development centres for assemblers).

This double hierarchy determines the type of product assembled in Spain, its role as a preferential destination for export to European markets and that multinational groups do not, in general, develop R&D activities related to product development in their Spanish plants. In general, it could be said that only automotive suppliers with Spanish capital develop R&D activities in Spain (Aláez-Aller *et al*. 2015).

In relation to the type of product assembled in Spain, the place occupied by Spanish automotive producers in the EU value chain has been limited to the assembly of vehicles with medium/low added value. A breakdown by segment of ANFAC data for passenger car assembly in Spanish plants reveals that this remained true in 2018, when 362,621 medium SUVs, 672,513 small SUVs, 596,083 small-sized vehicles, 441,562 compacts, 54,486 medium-sized vehicles and 83,029 large vans were assembled in Spain as were, additionally, 548,467 commercial vehicles and 55,499 industrial vehicles. In 2018, production was 2.8 million cars (2.2 million, 79 per cent, being passenger cars), of which 2.3 million were exported. With these figures, Spain is the second largest European manufacturer and the ninth largest in the world, with a 2.9 per cent share of the global market. Approximately 60 per cent of exports go to four European markets: France, Germany, United Kingdom and Italy.

The OECD calculates the value added contained in exports and their origin, domestic or imported. In the case of imports, this can be used as an indicator of the import content of exports. For 2015, this value was 40.7 per cent in the transport equipment industry compared to 31.2 per cent for manufacturing as a whole. This indicates a greater intensity of backward linkages – that is, greater integration in global value chains. In the same year, the automobile industry was responsible for 30.2 per cent of the imported value added contained in manufacturing exports (source: OECD).

Little is known about the situation of Industry 4.0 in Spain. There is no study that quantifies in any way the degree of implementation of such technologies and their impact. There are reports, usually official ones, on the extent of ICT focused on the deployment of networks, services, electronic administration, etc. (see, for example, Ministerio de Hacienda y Administraciones Públicas 2016), but this does not amount to data on Industry 4.0. Roland Berger (2016) does provide information on specific aspects of digitalisation, although these are agent assessments. One exception to this overall picture, however, is the report of the Observatorio ADEI (2017), which carried out a simulation exercise based on two scenarios: firstly, the convergence of advanced occupations with the United States, United Kingdom and Germany; and, secondly, the reduction in the working age population and the structural unemployment rate. On this basis, the Observatory estimates net job creation by 2030 of 2.4 million: 3.2 million jobs will be created in advanced occupations (jobs which are adaptable to digitalisation initiatives), with a further 0.6 million jobs added in occupations not susceptible to automation; while 1.4 million jobs will be lost.

Furthermore, the IFR (International Federation of Robotics) provides data on robots. Thus, in 2018 Spain ranked tenth in terms of annual robot installation (annual variations may be significant) with 5,300 units: far behind China, in first place with 154,000; and Germany, in fifth place with 26,700. In terms of robot intensity (robots per 10,000 employees), in 2018 Spain ranked 15th with 168 (the global average is 99), far behind Singapore (831), Korea (774), Germany (338) and Japan (327), which are in the leading positions, which explains the negative judgement made in reports and studies on the country's overall level of digitalisation (Roland Berger 2016; Bondar 2018). However, if we specifically consider the automotive industry, the situation is comparatively better: the intensity of robots was 1,110 in 2018 and Spain is in ninth position, in a ranking led by Korea (2,589) and with much less marked differences. This position is more in line with the weight of the Spanish automotive sector (second European and ninth worldwide manufacturer).

Some regional reports have, however, been prepared on the degree of implementation of Industry 4.0 based on company surveys. For example, AIN (2019) looked at Navarra; Bilbao, Camino and Intxaurburu (2016) focused on the Basque Country; Xunta de Galicia (2018) examined Galicia (with detailed reports for different sectors); UGT (2017) focused on Castilla y León; the Government of Aragon (2018) looked at SMEs in Aragon; and Hernández *et al.* (2018) examined Catalonia, which estimates the impact of automation in terms of a net creation of 13,000 jobs (+0.7 per cent) and a loss in manufacturing industry of some 12,000 jobs (-3.2 per cent).

3. Field survey

Our work aims to close the data gap by examining the incorporation of Industry 4.0 technologies in the automotive industry and the impact these are having on the industry. The empirical information comes from original field work which we carried out between October 2019 and February 2020. Given the absence of prior data, our approach has been to adopt the method described by Lewis (1998: 456) as 'iterative triangulation', based on 'systematic iterations between literature review, case evidence and intuition.' It is not a question of testing a theory, but of constructing one. Therefore, the sample is not random or stratified but, using the terminology of Eisenhart and Graebner (2007: 27), it is theoretical; that is: 'Cases are selected because they are particularly suitable for illuminating and extending relationships and logic among constructs.'

Our sample consists of the Volkswagen plant in Navarra, which manufactures two car models and is expected soon to start assembling a third; eight supplier plants (see Table 1); and various social actors consisting of a consultancy firm, a local automotive cluster and two trade unions.

The questionnaire, focusing on the issues revealed by a review of the literature, was validated through interviews with industry experts and academics. The effort was made to eliminate ambiguity in the questions (on the construction and use of questionnaires in operations management and manufacturing studies, see Flynn *et al.* 1990 or Synodinos 2003) and, in the end, two different questionnaires were used: one for companies and one for the social partners.

Information was obtained by conducting thirteen semi-structured interviews (the questionnaire consisted of structured and semi- or unstructured questions), so that interviewees could express their point of view in an open way. An e-mail was sent to firms and to social actors, explaining the purposes of the study and enclosing the questionnaire in advance so that the most suitable interviewees could be chosen and information collated beforehand. The interviews were conducted directly by the authors. This assured a high level of participation and prevented bias due to non-responses. This method also helped to prevent problems due to respondents misunderstanding questions, leaving some answers blank or incomplete, or answering inappropriately. Most of the interviews lasted between sixty and ninety minutes.

The questionnaire comprised 21 questions divided into six parts: identification; adoption of Industry 4.0 technologies; reasons for the implementation of these technologies; ways of incorporation; impact on employment and on job content and nature; and impact on headquarters strategy and the position of the subsidiary.

Our sample of plants (see Table 1) is characterised by an enormous variety of situations (origin of capital, activity within the automotive sector and size of plant) which limits the capacity to formulate detailed conclusions on the existence of differences in the implementation of Industry 4.0 technologies based on such variables. Nevertheless, the plants interviewed share a series of characteristics that are common to most plants in the automotive sector in Spain and which, as has been explained in section 2.4 of this work, are derived from how the Spanish automotive sector has developed: most of the plants are integrated into foreign capital MNCs; Spanish plants only undertake product-related R&D activity in very exceptional cases; the main activity of Spanish plants is assembly; and Europe is the main market for Spanish plants in the automotive sector.

Table 1 **Characteristics of plants interviewed**

Plant	Number of employees	Person interviewed	Origin of capital	Main activity	Position in the value chain
GKN	180	Quality manager; production department engineer	UK (Melrose)	Transmission; original equipment (short series); aftermarket	Tier 1
Vibracoustic	80	Plant manager	Germany	Chemical treatment of automotive parts	Tier 1 Tier 2
SAS	280	Plant manager	France (50%)/ Germany (50%)	Assembly; sequential deliveries	Tier 1
BENTELER	50	Plant manager	Austria	Assembly; sequential deliveries	Tier 1
Plásticos Brello	60	Plant manager	Spain	Plastic parts	Tier 1 Tier 2
Flex-n-Gate	100	Product engineer	USA	Welding; stamping	Tier 1
SKF	280	HR officer (training and staff recruitment)	Sweden	Bearings	Tier 1
Volkswagen	4,800	Process engineers	Germany	Car assembly	OEM
Grupo Aldakin	150	R&D department	Spain	Industrial automation and robotics	Tier 1

4. Analysis of results

4.1 Chronology of implementation of Industry 4.0 technologies

The companies interviewed recognise that the most relevant change as regards the digitalisation of their activity has been the integration of their production process with an ERP (enterprise resource planning) system. Compared to previous iterations, new model ERPs allow the production process to be directly connected to management tasks.

Firstly, therefore, the adoption of a new ERP means a considerable effort for plants, not so much financial as in adapting to the new system (business managers estimated the period of preparation of the plant before starting to use the new ERP was between nine and eighteen months). This change began in most of the plants interviewed around 2016; the timing for adoption, as well as the main characteristics, being dependent on the size of the plant and the origin and characteristics of the company that owns it. Consequently:

— it was adopted first in the largest plants with multinational capital, with smaller, locally-owned plants still in the process of implementing an integrated ERP. Meanwhile, larger companies are in the phase of obtaining greater advantages from integrated ERP and migrating it to the cloud;

— the type of ERP adopted by plants which are dependent on larger MNCs is usually SAP and was imposed by the company that owns the plant. Smaller plants and those with local capital have opted for other ERPs more suited to their characteristics;

— plants recognise the multiple advantages of digitised ERP: real-time process information; process control and stability; predictive maintenance; 100% traceability; paperless production; and a significant limitation of human error in decisions on the production process.

Secondly, the adoption of Industry 4.0 technologies has meant an increase in the degree of process automation which, according to plant managers, has been characterised by the following main features and timing (see also Table 2):

— the introduction of conventional robots continues on an upwards trajectory, at least in quantitative terms. However, technological advances in the field of industrial robotics are particularly uneven – the software has advanced significantly but the hardware barely at all. Consequently, there is no obvious technological break when it comes to traditional robots. This means that the limitations of robot hardware need, in a practical setting, to be both recognised and worked around before organisations can take advantage of all the possibilities that have been facilitated by advances in the software;

— the introduction of cobots is, however, recent (the first examples refer to 2017) and remains very limited. In some cases, the slowness of cobots (as opposed to traditional robots) has been mentioned as the main drawback which has limited their introduction to very specific cases, including the existence of clear ergonomic problems in a particular workplace;

— the first AGVs (Automated Guided Vehicles) in any of the plants in the sample date back to 2015, but their generalisation is more recent; in the majority of our plants, they started to be introduced from 2017 onwards although their use is progressing very quickly, especially with regard to operations within the plant. The enormous field for the development of these vehicles can be anticipated in that only one of the plants interviewed has recognised the use of AGVs in outdoor operations. The speed of their introduction derives from their advantages in terms of safety and reliability, the justification which lies behind the investment (a key argument for obtaining MNC authorisation for capital expenditure on AGVs is that they will replace active workers) and the financial facilities that AGV suppliers offer for their acquisition (as an example, it is possible to lease such vehicles);

— the automation of inventory control is spreading and the use of labelling has become general. However, examples of fully automated warehouses are rare and the substantial investment involved is only justified in highly particular cases even though the advantages of a fully automated warehouse are recognised by plant managers. One plant had invested in an intelligent, fully automated warehouse for the management of only one key component (an investment made in 2017). Where there are plans to build new warehouses, these will be digitised and automated but the automation of existing warehouses is an investment that appears to be lagging behind.

No direct link is recognised between process integration into the ERP and increased automation. As an example, in one of our plants, new conventional robots were purchased in 2014, prior to the adoption in 2016 of a new ERP.

The timing of the adoption of 3D printing follows very different patterns: the larger plants started using 3D printing around 2012 (they have recently replaced the initial machines with more sophisticated 3D printers); while smaller plants started using 3D printing in 2019 (where they are using it at all). All plants agree that 3D printing is not an option to replace, even partially, conventional production; yet all cite that it offers huge advantages in the manufacture of specific tools or prototypes.

The use of virtual reality and augmented reality in the production process is limited to R&D projects. Actual deployments of virtual reality are the case in only one plant (for the purpose of training workers before starting the assembly of a new product), while applications of augmented reality are currently being tested in two plants (in respect of maintenance tasks).

There is unanimity among the plants both on the huge accumulation of data on the production process resulting from its integration into the ERP as well as on the lack of strategies to take advantage of the analytical potential of this. Big data analytics is used in only two plants and for specific projects related to quality problems. For its part, the use of artificial intelligence has been practically limited to machine-vision in the identification of defects.

Table 2 **Industry 4.0 technologies introduced in automotive industry plants**

Industry 4.0 technology	Timing	
Integration of the production process with ERP system	Since 2016. Still in progress	Process control and stability; real-time information; predictive maintenance; 100% traceability = no paperwork
Automation (cobots)	Since 2017. Few examples	
AGVs	Since 2017. Fast development	Being rented. Adoption easy to justify (cost/benefit)
Inventory control and automation	Since 2017. Still in progress	
3D printing	Initially in 2012; most adopters since 2019	Limited use (no production): prototypes, tools, etc.
Virtual reality	Only in R&D	Training
Augmented reality	Only in R&D	
Artificial intelligence	Since 2018	Only for very specific problems
Data analysis systems	To be developed	

4.2 Process of introduction of Industry 4.0 technologies

The process of the introduction of the technologies encompassed by Industry 4.0 into automotive plants followed some common guidelines in the majority of plants in our sample. The initiative for introducing a particular technological improvement starts with the plant in most cases, with original ideas found usually among local suppliers of capital goods and in local engineering companies that have worked on previous projects with the plant.

The main problem faced by plants in adopting technological improvements relates to the need for the approval of capital expenditure by the head office of the company that owns the plant. Plants have very little autonomy in capital expenditure decisions and, therefore, have to seek approval by submitting a justification that, in most cases, involves recovering the planned expenditure over a very short period of time (periods of one to three years). The probability that the submitted project will be approved is increased where its implementation involves a reduction in the workforce. In this process, the plant manager takes on special significance since he or she is the direct link to MNC decision-making centres, and his or her ability to sell the plant proposal is key in obtaining final approval for it.

It is not common for the MNCs which own plants to impose the adoption of Industry 4.0 technologies on any plant, except in the case of ERP for which the MNC will have negotiated licences for use throughout the company. The remaining projects are very specific to the plant and respond both to the need to solve specific problems and to the plant's capacity to realise process improvements.

One of the business managers interviewed considered that the origin of the introduction of Industry 4.0 technologies could be linked to a change in mentality at the plant around 2012, when the search for solutions to production challenges was directed towards the outside while, at the same time, collaboration between company departments was increased. In contrast, the previous path to resolving production problems had been to rely almost exclusively on internal resources.

According to our interviewees, the internal dynamic of the plant is the key factor in differentiating between those plants that are actively adopting new technologies and those that are simply replicating the experiences of neighbours or adopting the suggestions of MNC headquarters.

4.3 Main advantages of the introduction of industry 4.0 technologies

The main advantages that the plants recognise arising from the adoption of Industry 4.0 technologies are summarised in Table 3. The specific characteristics of the plant determine the type of technologies that are of special interest to each one. As an example, suppliers working on sequential deliveries for a vehicle assembly plant must meet a very strict schedule of cost reduction over the lifetime of the assembled model and, therefore, feel specific pressure to achieve continuous cost reductions. In addition, the plant's ability to meet the planned cost reduction schedule is a key feature of being able to win new assembly supply contracts when the assembly of a new model is being negotiated. These sequential delivery plants do not have the capacity to influence the production awarded and, therefore, the technologies introduced will focus mainly on cost reduction and on resolving known quality problems.

On the other hand, unlike supplier plants working on sequential deliveries, one of the plants in our sample is responsible for a very specific product, the demand for which is met in short runs. Here, the introduction of new technologies has been aimed fundamentally at achieving a greater degree of flexibility as well as offering an image of innovative capacity that will encourage the award of new contracts.

In addition to these specific aspects, all the plants also include among the advantages of adopting these new technologies their positive effects on quality, the health and safety of workers and the image of the plant. The latter is key not only with regard to customers but also within the MNC itself, in the context of plants recognising that increased levels of competition are not only external but also internal as regards other plants within the company.

Table 3 **Main advantages to the introduction of Industry 4.0 technologies**

Industry 4.0 technology	Cost reductions	Quality	Productivity	Health and safety at work	Plant image	Labour shortages
Integration of production process with ERP system	✓	✓	✓		✓	
Automation (cobots)	✓	✓	✓	✓	✓	
AGVs	✓			✓	✓	
Inventory control and automation	✓			✓		
3D printing	✓		✓			

4.4 Impact on working conditions and employment

One of the sections of the questionnaire was specifically designed to examine the effects of the adoption of new technologies on employment and working conditions.

With regard to the quantitative effects on employment, all plant managers agreed that there have been no redundancies directly linked to the introduction of Industry 4.0 technologies, although they do acknowledge that there have been relocations of workers due to the further automation of certain phases of the process. In this sense, new technology is running in an apparently contradictory direction to the general idea that such technologies fundamentally presuppose the substitution of human intervention with machines. The only obvious reduction in the number of workers is associated with the introduction of AGVs, which clearly replace forklifts. Nevertheless, it is acknowledged that the plants are in a process of reducing the workforce in the medium- and long-term, and are trying to do so while not generating enforced lay-offs.

With regard to changes in the qualifications and skills of workers, the increase in the level of digitalisation and automation of plants has meant:

- new skills on the part of maintenance employees, especially with regard to programming, which complement their traditional mechanical skillsets;
- new profiles of recent hires which recognise the need to have increased IT specialists among staff;
- new recruits will have a higher level of training than previous intakes, requiring, even for operator positions, a minimum level of occupational training.

However, suppliers in the chain recognise that the new machines introduced into the process do not require particularly sophisticated skills since improvements in the human-machine interface, together with job-specific training, make it easier for an operator to remain at his or her post and take on other, simpler tasks. The digitalisation of the process and automation have reduced the contribution of the human factor to key decisions in the production process, such as what to produce and in what quantities, the diagnosis of problems, etc., but have not meant the total elimination of the operator who now has to assume the previously peripheral tasks of monitoring the machine, cleaning, etc.

Our interviews allow us to anticipate a future in which increased automation may nevertheless reduce the number of operators in a plant while increasing the number of people employed in maintenance tasks. Simultaneously, the decreasing number of operators will not require a very high level of training while those occupied in maintenance will have to improve their level of competence in terms of being able to carry out programming tasks to take charge of production equipment that is increasingly sophisticated.

Training activities in plants have, therefore, been partially affected by the introduction of Industry 4.0 technologies. On the one hand, the introduction of changes in the ERP and increasing automation have been accompanied by specific training, provided by external companies as part of the contract for the implementation of new technologies. On the other, the training of the workforce in general, and of maintenance staff in particular, must increasingly encompass IT and programming courses.

In any case, there is a general recognition that an increase in automation has meant improvements in the ergonomic conditions of the workplace.

4.5 Position of plants within MNCs

In the automotive sector, a tendency has been detected for MNCs to encourage competition between plants so that the allocation of workload for each depends on its competitive position within the MNC. As has already been pointed out, the plant managers we interviewed recognise that the initiative for the introduction of new Industry 4.0 technologies corresponds, for the most part, to the level of the plants themselves. It is the plants, therefore, that have the autonomy to decide which technological improvements they would like to carry out, although the authorisation of capital expenditure is the responsibility of the headquarters. Although the introduction of Industry 4.0 may be undermining the locational advantage of the availability of flexible and cheap labour, the plants in our sample do not perceive their position within the MNC to be affected in this regard. However, they do recognise that they are being continuously monitored as regards their profitability which, in many cases, depends directly on the costs of production. Some of the plants in our sample work on sequential deliveries and, therefore, their current location is completely dependent on the location of their customer's plant.

Once a technological improvement has been introduced in one plant, it would be possible to extend this to the rest of the plants within the MNC. At this point in the process, plants realise that there are two, opposing effects that the dissemination of their Industry 4.0 improvements could have on the position of their plant within the MNC:

— on the one hand, a plant that is very active and successful at introducing technological innovations could, in disseminating them to the rest of the plants owned by the MNC, achieve a certain prestige as an agent of technological improvement, thus strengthening its position within the MNC;

— on the other, the rapid diffusion of such improvements to other plants (normally competitors within the MNC) could erode the advantages of the plant in terms of cost and quality. This would recommend the delay of such diffusion in order to maintain the competitive advantage obtained over the other plants in the company.

In this sense, our interviews suggest that MNCs have not developed formal systems which facilitate the dissemination of technological improvements among the plants. In the interviews we conducted, only one case could be recognised of an MNC that has developed an incentive system in which plants could share technological improvements. Within the plants we interviewed, there are instances of the application of an Industry 4.0 technology being first developed in the Spanish plant and then transferred to other plants in the group. In one case, a Spanish engineering company that had worked with one of the plants was hired by another MNC plant located in a central and east European country in respect of the digitalisation of its production process.

In principle, it could be anticipated that MNCs might develop a common services department that would promote the adoption of Industry 4.0 technologies throughout the group. In this instance, all the plants supplying the MNC would work under the same system and with a very similar process, sharing technological problems and solutions.

The extreme case would be represented by those MNCs that operate on the basis of sequential deliveries, with the geographic location of their assembly plants adjusted to the location of their customers. Here, it might be acceptable for some plants, depending on their location, to carry out activities relative to their own locational context, which may require alternative technological solutions. For example, in one location the problem might be a poor energy supply, which would encourage the introduction of more energy-efficient technologies; while in another the main problem might be labour shortages, which would naturally encourage a greater degree of process automation to reduce the need for labour. In this sense, the strategy of granting the initiative for the introduction of Industry 4.0 technologies to the plants themselves would be rational since the problems faced by each are highly dependent on the economic context of their location.

Even here, however, this should be complemented with the existence of internal mechanisms within the MNC that encourage the dissemination of technological improvements among the plants, granting decision-making capacity on their adoption to the plants' own management teams. A strategy that promoted adaptation to the local environment in terms of collaboration with local companies while, at the same time, promoting the dissemination of solutions across the group would create a level of competitive advantage over and above what we detected was the case for most of the plants in our sample.

5. Conclusions

Since the introduction of the term 'Industry 4.0' to refer to a virtual fourth industrial revolution (Kagermann *et al.* 2013), numerous papers have been published with the aim of estimating the effect of the introduction of these new technologies on employment and, even more relevant for those countries without domestic capital MNCs, to estimate the possible backshoring effects of assembly activities. Most of the work has focused on anticipating the macroeconomic effects on the labour market in the medium- and long-term, but this has not provided information on the qualitative aspects nor on the degree of implementation of Industry 4.0 and the resistances and complications that could occur during the adoption process. The work on which this chapter is based has been intended to contribute to the literature on the subject by providing qualitative information obtained directly through interviews.

Our area of study has been focused on the automotive sector (one of the most dynamic in the adoption of Industry 4.0) and plants located in Spain, both that of an assembler (VW group) and those of eight different tiered suppliers.

Our analysis of the information obtained through field work allows us to recognise a process of an increasing level of digitalisation (mainly through the integration of the production process with the company's ERP), starting about five years ago. At the same time, although independent of digitalisation, automation is increasing. No structural change seems to be detectable, but there has been an intensification of this process (an increase in the number of robots and the introduction of AGVs). In addition, those we interviewed recognise that greater digitalisation has allowed a huge amount of information to be accumulated on the production process, but it is also accepted that, for the moment, all this information is not being used.

The research highlights that initiative over the introduction of Industry 4.0 solutions lies at plant level and is particularly dependent on the motivation of the personnel directly involved, including the process engineers (in detecting possible improvements) and the plant manager (in negotiating to gain authorisation for capital expenditure from MNC headquarters). The introduction of this technology in Spanish plants is being carried out with the collaboration of local agents: engineering companies; capital goods suppliers; technology centres; and, to a lesser extent, universities. The changes indicated have not, for the moment, led to appreciable cuts in employment, although there are indications of the reassignment of workers to new tasks and a demand for new profiles and new skills in certain jobs (for example, maintenance personnel being required to have programming knowledge).

The increase in the degree of digitalisation is still very recent and the essential characteristics of the process of introducing these new technologies remain in the definition phase. However, both the ability to introduce such innovations and to adapt those that have been developed are key issues in determining the competitive position of plants and companies. This is even more relevant when the analysis focuses on an environment as competitive as the automotive sector, in which competition between regions and countries is determined not only by competition between companies but also by growing internal competition within the company, manifested in the closure of some plants and the expansion or opening of new ones in different locations. It was particularly interesting in the light of this that MNCs do not have formal systems for disseminating the innovations introduced in a plant to the rest of their plants working in the same sector.

To this context, which is volatile and in which competitive pressures are acting in different directions, not only in that of digitalisation, we must add the uncertainties generated by the switch to electric vehicles and changes in demand behaviour and in the form of car ownership, as well as mobility patterns. This may condition, and certainly deepen, some of the trends observed as a result of the implementation of Industry 4.0 technologies.

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Chapter 5
Industry 4.0 and the prospects for domestic automotive suppliers in Poland

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1. Introduction

Industry 4.0 is claimed to be one of the important triggers of smoother work organisation, significant modernisation and higher innovation performance. Industrial policy is currently being modernised in many countries (e.g. France, US, Japan and China) and aimed at the reorientation of national economies towards the requirements of the Fourth Industrial Revolution in order to maintain and restore workplaces or improve competitiveness and added value in the domestic sector (Roland Berger 2016). However, little is known about the role of Industry 4.0 in the potential upgrading of companies driven by the implementation of digital solutions (Szalavetz 2019). As the fourth industrial revolution now underway will dramatically change the way business is conducted, special attention should be paid to the impact of these new enabling technologies on domestic small and medium-sized enterprises (SMEs) and entrepreneurs, who constitute the major part of the local economy in several regions and form critical assets for their successful and sustainable development. The key question is whether the adoption of Industry 4.0 may provide opportunities for small and medium-sized enterprises and entrepreneurs to move up within global value chains (and avoiding stagnation).

Current radical advances in manufacturing technology are often described under the umbrella term 'Industry 4.0'. The fourth industrial revolution relies on a combination of business and manufacturing processes which, due to the implementation of digital technologies, should allow the integration of all actors in a company's value chain (Rojko 2017; Gracel and Łebkowski 2018). The following solutions and systems are usually classified as Industry 4.0:

a. cyber-physical systems;
b. various technologically advanced solutions, including:
   - smart analytics solutions;
   - smart decision-support solutions;
   - smart solutions in intra-plant logistics, production scheduling, product development and testing, etc.

Our research on the role of contemporary changes in the domestic sector and on digital transformation is focused on the Polish automotive industry, which holds a significant position in central and eastern Europe (CEE) in terms of its employment growth and overall potential. Part of the integrated periphery of the EU, Poland attracts numerous foreign companies involved in various global production networks. The share of value-added created in foreign-owned companies has reached 90 per cent in the CEE automotive industry (Pavlínek 2017). Hence, it must be argued that, with low labour costs and a low share of work in value creation (Pavlínek 2018, 2020), the CEE automotive industry (and in Poland in particular) remains export dependent. The extent of domestic companies' involvement in global production networks is relatively limited (Guzik *et al.* 2020).

We have investigated whether, and how, Industry 4.0 technologies are influencing the position of domestic suppliers (companies with a dominant share of Polish capital) within value chains in the automotive industry. In this chapter, we argue that a vicious circle exists in upgrading, illustrated by the various constraints being experienced by domestic suppliers. It is argued that positive attitudes towards the introduction of new technologies among managers of domestic automotive companies are rather the exception than the rule. To sum up, we argue that digital transformation facilitates neither the internationalisation of local SMEs or global value chain integration in Poland.

Our research is based both on primary and secondary data combined with a literature review of the position of the Polish automotive industry and the role of domestic suppliers within it. Fourteen interviews were conducted covering successful automotive suppliers (six interviews), 'digital entrepreneurs' – providers of Industry 3.0 and 4.0 solutions[1] – (six interviews) and key public stakeholders (two interviews) representing institutions promoting the implementation of Industry 4.0 and managers of automotive clusters (see overview in Appendix). Automotive suppliers in the sample were selected on the basis of information obtained from, and the recommendations of, key personnel both among managers of automotive clusters and from IT & automation companies delivering Industry 4.0 solutions to the market. Data collection has been triangulated with a variety of secondary sources of information in order to enhance the reliability of our observations and conclusions.

This chapter consists of three main sections. The next section briefly discusses the Polish context and concentrates on the position of and current changes in the automotive sector in Poland, with a particular focus on the role of domestic suppliers. The main findings of the chapter can be found in section two and these are summarised in the last section.

2. Setting up the Polish context

2.1 Snapshot of the current state of the automotive industry in Poland

The automotive industry is the second largest manufacturing sector in Poland both in terms of production and exports. The role of this industry in Poland has been continually strengthening in the last three decades and, together with other CEE economies, the country has become one of the world's fastest growing centres of the automotive industry,

1. Industry 3.0 solutions include robotisation and the automatisation of manufacturing whereas Industry 4.0, as the next step, further entails the digitalisation of production processes.

second only to China.[2] Currently, around 1,000 producers are active in Poland, with total employment exceeding 214 thousand, which makes Poland's automotive industry the third largest in the EU after Germany and France. This development has been driven by massive foreign direct investment. More than 330 new automotive factories were built in Poland in the years 1989-2017, four-fifths of them by foreign investors (Domański and Gwosdz 2018). The country specialises particularly in components, parts and buses, while the dynamics of passenger car manufacturing substantially lag those of other CEE countries: Slovakia, Hungary and Czechia in particular.

The Polish automotive industry is positioned in the spatial division of labour as an integrated semi-periphery (Guzik *et al.* 2020; Pavlínek 2012, 2017, 2018, 2020; Krzywdziński 2018). Poland (along with other CEE countries) still performs a dual role, and low value-added and labour intensive products still constitute a substantial part of total output (one-third, according to estimates by Guzik *et al.* 2020). Gradual industrial upgrading is underway; however, the scope of functional upgrading is relatively limited, especially in comparison with the role of the country in production. Thus, the dependence on foreign firms and the secondary role of indigenous producers (discussed in greater detail later in this chapter) is a significant weakness.

2.2 The role and position of domestic suppliers

There are 280 companies with dominant Polish capital in the broadly-defined automotive sector in Poland (Table 1) and they bring together one-fifth of all employment in the automotive industry in the country. Less than seven per cent of them can be regarded as big companies in terms of employment or revenue (above 250 employees or €50m in revenue). Medium companies represent the core segment of the industry, while small companies are also numerous (Table 1).

Table 1 **Automotive companies in Poland with predominantly domestic capital, by size**

Company size (number of employees)	As of 2018		Company size (revenue) in €m	As of 2017	
	No. of companies	Employment in thousand		No. of companies	Total revenues EUR millions
1,000 and more	3	5,800	100 and more	7	2,560.0
500-999	9	5,628	50-99.9	14	969.4
250-499	21	7,198	10-49.9	75	1,565.5
50-249	149	20,136	5-9.9	51	378.4
10-49	56	1,795	Less than 5	86	191.2
No data	42	–	No data	47	–
Total	**280**	**40,557**	**Total**	**280**	**5,664.5**

Source: authors' research

2. Dynamic growth and its implications have been widely documented and discussed in the research literature; see, among others: Domański *et al.* (2013); Domański *et al.* (2018); Drahokoupil (2009); Jürgens and Krzywdziński (2009); Krzywdziński (2018); Nölke and Vliegenthart (2009); Pavlínek (2012, 2017, 2018, 2020); Pavlínek and Ženka (2016) and Szalavets (2012).

Domestic suppliers represent all segments of component production, with the largest number being in the manufacture of plastic parts, metal and stamped parts, technological elements and electric components. Three-quarters of domestic producers are, predominantly, tier two suppliers. About 30 per cent deliver at least part of their production directly to OEMs, though only eleven per cent are predominantly tier one suppliers; production in the rest is focused more on tier two suppliers or for the aftermarket. Design competence is most common among tier one suppliers (25 per cent of plants) but very rare among lower-tier producers which are, in the main, subcontractors.

Although there is a clear growth of, and fast learning among, domestic tier one and tier two component producers, which are capable of providing high product quality and reliability of delivery, there is only limited progress in design competence among domestic companies. Only twenty-nine plants have competencies within product design (according to the requirements of IATF 16949). A relatively new trend is the emergence of independent start-ups, offering design and R&D services (for example Cadway Automotive in Rzeszów, CADM Automotive in Kraków and ctrlCAD in Katowice).

The analysis conducted in this research study and also in previous papers (see Domański *and Gwosdz* 2009; Pavlinek *et al.* 2009; Guzik *et al.* 2020) confirm that there is an ongoing development of companies that are participating in the automotive supply chain (reflected in growing revenue, increases in the range of products, development of tooling shops and construction departments and significant activity in obtaining EU funds). This has resulted in some companies becoming product specialists.

A recent phenomenon, which started after 2010 and gained momentum in 2015-2017, is the international expansion of Polish companies. This 'going international' trend (whether through greenfield investments or mergers and acquisitions) is associated primarily with the opening of a window of opportunity for Polish companies, which turned out to be the 2008-2009 crisis in the industry (Domański *et al.* 2013). None of the Polish producers expanded to core (western European) markets before 2010 and, in the early 2000s, only one Polish manufacturer – Groclin – decided to locate its activities outside the country, with the dominant motive being cost reduction. The motivations of companies that began international expansion during the last ten years are fundamentally different from considerations made prior to the crisis – cost-driven expansion has not been a particularly relevant factor in any of our investigated cases. Instead, it has been about the diversification of operations in the entire group (acquisitions made by Boryszew); expansion within the main activity by entering new markets (Wielton, Alumetal, Izoblok, Sanok Rubber); or following customer strategy (greenfield investments by Boryszew and Sanok Rubber). It must be stressed here that most of the Polish companies which have internationalised had previously achieved a significant position in the domestic market, be it in the automotive industry or in other business segments. In this sense, their growth can be significantly interpreted as a staged development in the internationalisation model (IP model, also called 'Uppsala model') (Johanson and Vahlne, 1977). The only exception is Izoblok, a Chorzów-based company whose mode of development can better be described by the concept 'born global' (Knight and Cavusgil 2004; Madsen and Servais 1997).

The share of manual operations is still significant in the plants owned by leading Polish manufacturers. As one of our key public stakeholders remarked, they ‘are currently in the phase of a difficult leap from Industry 2.0 to 4.0’. Strategies in these companies mostly aim at the comprehensive implementation of automation and robotisation (Industry 3.0), especially in the new production departments of companies launched both in Poland and abroad; however, up to now none of them have clearly declared in their strategy the desire to show strong leadership towards Industry 4.0.

Barriers to the growth of domestic producers in the (semi)periphery to becoming European/global suppliers are stronger now than they were ten to twenty years ago. This is due to: consolidation among the major automotive suppliers; the need to be present in various regional markets (Asia, America, Europe); the growing complexity of supply networks; and greater design requirements. The vicious circle which limits the functional upgrading of domestic suppliers is driven thus: the lack of design competencies constrains profitability which, in turn, reduces investment and development capabilities. A small scale of production alongside a low level of R&D competence has made it impossible to meet OEM expectations – including among the capital and organisational abilities to follow new client projects. Furthermore, small-scale production and the lack of design competencies (and, therefore, prospects for contracts for new projects with higher profit margins) enables the harvest only of ‘transfer projects’, hindering the possibility to upgrade within value chains. Only a few Polish companies have managed to break out of this vicious circle. It must also be stressed that some local companies are quite satisfied with their tier two position, perceiving promotion to tier one status not as an upgrade in their position in global value chains but rather a substantial risk to the company’s existence [Interview COMP-08].

Where can the opportunities for domestic automotive firms be found? Four main areas can be underlined in this regard:

— hybridisation: the involvement of non-automotive segments, or integration with other sectors. Several Polish companies (especially those producing plastics and metal components) combine deliveries to the auto industry with production for home appliances, electronics and construction industries;

— niche products: the ability of Polish companies to acquire competitive advantage has, after the 2008-2009 crisis, been directly related to the cost benefits and greater flexibility achieved from meeting specific customer requirements. This results from the establishment of market niches in the earlier period, above all in labour intensive segments (various products ranging from trailers or semi-trailers for special purposes, construction and protective components made of plastics and aluminium to demanding and technologically-sophisticated production services);

— developing close cooperation with other SMEs, either directly or via cluster initiatives enabling full-service supply thanks to the complementary capabilities of other network participants. This innovative strategy as far as Polish territory is concerned has been promoted by the members of the Polish Automotive Cluster

(PGM), with the members of the cluster recently initiating the establishment of a 'PGM' joint commercial brand;

— the aftermarket.

3. Effects and scale of Industry 4.0 in Poland

Major interest in Industry 4.0 solutions in Poland has been expressed by foreign-owned companies. A survey conducted on a large sample of manufacturing companies by Astor in 2017 (ASTOR 2018) shows that a growing number of companies have also started activities aimed at recognising the possibilities of transformation into Industry 4.0. However, the Astor research revealed that only seven per cent of factories had started or partially implemented any Industry 4.0 technologies or solutions (mainly in the form of Manufacturing Execution Systems). Moreover, not only the level of digitalisation but also the level of automation remains low. Hence, companies have first to face up to the third industrial revolution: in 2017, some fourteen per cent of manufacturing plants had still not entered Industry 3.0 (ASTOR 2018). Interest in the automation of manufacturing (Industry 3.0) stems from the decreased cost of technologies but, according to Astor, the *leitmotif* is pressure from customers to reduce costs and shortages of highly-skilled employees. The initial trigger (observed especially in SMEs) is related to price negotiations that do not end up in a deal due to high prices. This is endangering the position of Polish SMEs in supply chains (ASTOR 2018).

Interviews with managers of automotive companies confirm the above data. 'Many automotive companies are still far from automation. Half automation – we are here. This is a big threat to companies with Polish capital. In order to exist, it is necessary to automate. Some companies do not know how to do it or why they are doing it. They look at it, as they did ten years ago, and then it did not make financial sense because labour costs were cheap. And I have the impression that many companies are still there. In the end, this is an investment and a risk. The problem is that some have overlooked the period when it was necessary to get into automation. Companies must go in this direction and, if they do not go, they will fail. But automation is a change, a challenge for organisation' [Interview COMP-07].

In interviews conducted among our automotive companies, suppliers of Industry 4.0 solutions and key public stakeholders, three strategies for domestic automotive companies regarding digitalisation have been revealed.

First is the most common sceptical attitude which relies on the passive observation of new solutions. Many Polish companies agree it is necessary to enter the fourth industrial revolution but, for now, they have decided not to implement Industry 4.0 solutions. This is due to several organisational (managerial), financial, intellectual and technological barriers (Table 2).

Table 2 **Main challenges to implementing Industry 4.0 in companies with domestic capital in Poland**

Domain	Main barriers
Management	– Low level of openness to cooperation – Low level of project and process management – Low level of use of IT tools among managers
Human and social capital	– Low social capital; lack of mutual trust between entrepreneurs, and sometimes even mutual hostility; unwillingness to cooperate; lack of courage in undertaking risky investments – Shortage of young automotive specialists; ageing practitioners – Outwards migration of outstanding specialists
Technology	– Too weak involvement of R&D units for cooperation with the SME sector
Financial	– Low availability of funds for research and implementation of innovation in automotive companies – Low and falling profitability of companies (seven per cent in 2012 to less than four per cent in 2018) – Difficult access to external financing for companies in the SME sector

Source: Interviews with managers and key public stakeholders

When Polish managers or owners recognise that, during the implementation of Industry 4.0, there is a need not only to change the technological solution but also to rebuild the whole company in terms of its management, they resign from this path. This obstacle is related to the limited competencies of chief engineers and the fear of exchanges with staff. The following quotation summarises it well: ‘You have to look at this in the concept of habits; these engineers have always acted in such a way – why should they change it?’ [Interview ORG-09]. As another respondent claimed: ‘Polish SMEs have not gone mentally through the development stage – to measure the process and to improve it’ [Interview COMP-01]. Meanwhile, in other departments of the company, especially those in which financial analysis is being carried out, there is increasing wage pressure and a belief that something must be done about introducing automation and digitalisation.

Secondly, the current stream of EU funding is focused on supporting R&D activities, not purely on the implementation of digitalisation or automation itself. Hence, medium-sized companies are gradually implementing Industry 4.0 solutions and technologies after carrying out R&D activities. The introduction of new solutions is being done on a step-by-step basis and so the implementation of Industry 4.0 is not holistic. Such a strategy may even be based simply on a desire to distinguish one’s companies from other suppliers and for higher prestige among western customers (Table 3).

Thirdly, a long-term corporate strategy aimed at full automation and transition to a higher level in the value-added chain ought to be a necessity for many firms. However, radical implementation (a total redesign of manufacturing processes and management) of Industry 4.0 is uncommon and very rarely takes place even in newly-constructed factories. One of the interviewees summed this up by arguing that digitalisation and Industry 4.0 have become slogans and symbols for the introduction of new technologies. ‘But everyone draws from these solutions what they need. Not everyone needs a fully automated factory’ [Interview COMP-06].

Polish automotive companies which may be classified as tier two suppliers are still far away from Industry 4.0 and even 3.0. It is not yet sure whether the profile of domestic suppliers is suitable for Industry 4.0 solutions. Indeed, no domestic automotive suppliers has gone wholesale into Industry 4.0. To sum up, there is only a limited chance for the whole automotive industry to enter the digital age of manufacturing. At the current stage, we can talk rather more about implementation pilots for Industry 4.0 in firms with predominantly Polish capital. The main method is to implement solutions in small steps – a systematic implementation of individual solutions in existing production lines [Interview COMP-10]. Our research shows that companies are especially eager to implement methods and technologies in the area of predictive maintenance.

An overview of existing pilot schemes in selected Polish automotive companies is provided in Table 3.

Table 3 **Motivations, applied technologies and the results of implementing Industry 4.0 in selected automotive companies with predominantly Polish capital**

Motivation behind implementation	Main technology applied	Results achieved
A long-term strategy of the company aimed at full automation and transition to a higher level in the value-added chain	CPS data collection and analysis (PQS); fully automated gas-spring production line	1. Improvement in the production process and in product quality (greater stability of quality) 2. Reducing the number of employees and increasing their skill level 3. Lower quantity of waste
The will to distinguish the company among other suppliers; raising the prestige of the company among customers in the west; increasing production capacity; ensuring replicable quality in a demanding technological process	Fully automated and robotised welding line; CPS data collection and analysis	1. Greater process control and optimisation of the product's manufacturing cost 2. Greater comfort of service work, increasing the skills of the team 3. Authenticating the very high product quality in the eyes of customers
Implemented as an experiment, the secondary motive was the reduction of labour costs	Fully automated processing line for thermoplastic materials; IT unit for the central management of injection moulding processes; advanced quality control systems (AQC); CPS data collection and analysis	1. Obtaining the replicability of the production cycle 2. Adherence to a time operation regime 3. Technological production stability 4. Saving on losses, malfunctions and defects 5. Good information flow (facilitating responses to complaints)

Source: Interviews with managers and company data

3.1 The impact on human resources

The main factor accelerating the digitalisation of the Polish automotive supply industry is the current labour market situation, in particular the increase in labour costs [Interview COMP-09] and staff shortages. This was well summarised by one of the managers of a global automotive tier one company operating in Poland: 'When it comes to Industry 4.0, the conditions in the labour market gave us this gift so we could engage in 4.0 solutions;' while another remarked: 'Industry 4.0 is a direction that we can not avoid because of the human and economic factor (...) When there is a problem, we want to know where it is. We want to combine data about production' [Interview COMP-08].

Introducing Industry 4.0 solutions in a company spurs substantial changes in its skills breakdown. As one of the managers we interviewed emphasised: 'The company will increasingly rely on more skilled employee segments, like constructors as well as IT specialists' [Interview COMP-12]. Another interviewee stressed: 'Because we made a conscious decision systematically to increase the level of automation and robotisation, now we need engineers, not production workers/operators. The ideal situation would be if we did not have operators at all, only automatic lines and engineering staff' [Interview COMP-07].

With the push to automate, there are expected to be limited job losses among production workers in companies introducing Industry 3.0 and 4.0 solutions. However, given the relatively low technology level among the majority of domestic suppliers, major job losses may emerge in the future as a result of company failures to survive in the competitive automotive market. Digitalisation will represent a serious threat to further competitiveness if technological change turns out to have a disruptive pace and range.

Industry 4.0 requires an interdisciplinary and interdepartmental approach, as well as a combination of knowledge and skills in several areas (Gracel and Łebkowski 2018). This combination manifests itself firstly in attitudes towards operational and managerial change. Our research reveals the existence of intellectual barriers at the managerial and company ownership levels, but also as regards engineers and production workers. At the highest management level, there is the problem of accepting innovative solutions due to high costs while there is, simultaneously, a lack of searching for comprehensive solutions. There are also, overall, reactive attitudes to changes in the labour market [Interview COMP-01]. At the mid-management level, the conservative approach to the training of engineers in Polish companies weakens the possibilities of using Industry 4.0 solutions (ASTOR 2017). At shopfloor level, new solutions increase the scope of processes that fall on a single employee, thereby increasing responsibility. The shortage of human resources and position mismatches are one of the major barriers to the development of Industry 4.0. The ability to learn, unlearn and relearn is relatively low in Poland.

As emphasised by respondents, there is a significant problem with finding larger groups of engineers with the required skills to handle larger projects. This gap may, partially, be filled by transfers from international companies. The second chance for Polish automotive companies seems to be the use of human resources from related industries. New areas of technical competence will gain in importance, such as the integration of IT systems control techniques and the integration of analytical methods in data clouds with local networks or cyber security. This will lead to the search for highly-skilled engineers in automation, robotics and software, production engineers, designers of automation systems and mechatronics, and designers from the virtual reality world or gaming.

3.2 Public policy response

The Strategy for Responsible Development, an instrument launched recently by the Polish government to manage the main development processes in Poland, identifies five development traps that Poland faces, including the 'average product trap'. The authors of the plan highlight – among others – that R&D expenditure amounts to less than one per cent of Polish GDP. They also stress the slightly awkward findings that only thirteen per cent of SMEs innovate (compared to 31 per cent in the EU) while only five per cent of exports originate in high-tech sectors (https://www.miir.gov.pl/media/14873/Responsible_Development_Plan.pdf).

This section offers a short look at the current support instruments introduced by the Polish government which are aimed at accelerating and facilitating the transition of the Polish economy into Industry 4.0.

The main activity is the Platform for Future Industry (4.0) (*Platforma Przemysłu Przyszłości*) which started its operation at the start of 2019 as a foundation under the Council of Ministers. The role of the Platform for Future Industry (4.0) is to integrate and accelerate the transformation of the Polish economy towards Industry 4.0. The Platform's project also encompasses the integration and coordination of activities for suppliers, research centres and various entrepreneurs, from both the public and the private sectors. Moreover, the Platform will help in the setting-up of a cross-linked business ecosystem (company network) and the coordination of Digital Innovation Hubs (DIH), and will also provide access to instruments and tools aimed at stimulating interaction between companies and research institutions (https://www.mpit.gov.pl; http://przemysl-40.pl).

Andrzej Soldaty, President of the Management Board of the Platform for Future Industry (4.0) foundation, argues that the government's involvement in the implementation of Industry 4.0 extends to measurable effects in the area of the better use of resources and the better use of market opportunities. In his opinion, 'Not entering the 4.0 level and not becoming competitive poses a great threat to the whole economy,' while the role of the Platform for Future Industry (4.0) should be to raise the competitiveness of enterprises by supporting digital transformation. The Platform's aim is to support development in four areas: market; business environment; technology; and people. Soldaty distinguishes two main roles of the Platform: the first is in creating and recommending, based on developments in knowledge and skills, but also in providing formal and legal solutions and financial resources; the second is to enable 'coopetition' – to encourage competition and cooperation among enterprises by building networks and establishing thoughts, concepts and common goals in order to raise the level of advancement.

Assistance in carrying out changes in enterprises will be delivered by regional initiatives named Competence Centres (*Centra Kompetencji*) whose role is to offer developed support instruments, such as workshops and training, and other comprehensive services for enterprises. Furthermore, the Centres will be responsible for cooperation between research institutions, technology providers, engineering companies and business partners. In 2018, three regional Competence Centres were opened in the Mazowieckie, Wielkopolskie and Śląskie regions (https://www.mpit.gov.pl). In addition, the Ministry of Entrepreneurship and Technology, together with the three Universities of Technology – Silesian, Warsaw and Poznań – prepared in 2018 a pilot project named the 'Incubator of Industry Leaders 4.0' (*Inkubator Liderów Przemysłu 4.0*). The main aim of the project is to train staff in the Competence Centres and in the Platform for Future Industry (4.0).

In 2017, a Sectoral Programme of Scientific Research and Development (INNOMOTO) was launched by the National Centre for Research and Development and the Polish Chamber of the Automotive Industry. INNOMOTO supports the implementation of large R&D projects and aims to increase the number of innovative solutions. The co-financing of projects can help entrepreneurs create new, or expand existing, R&D departments as well as develop innovative technologies and products. In 2017 and 2018, 57 projects were co-financed by INNOMOTO to a total amount in excess of PLN 326m (https://www.ncbr.gov.pl/; http://innomoto.com.pl).

One of the tools of innovation policy formation has been the revision of the tax law in Poland, which took place in the second half of 2017. The purchase cost of industrial robots and 3D printers can now be written off more efficiently. The government hopes that new incentives will encourage companies, small and medium-sized enterprises in particular, to invest in new technologies and solutions.

The main weakness of the tools and solutions implemented by the government is the lack of the necessary flexibility in the case of R&D activities. The specificity of innovative projects often forces changes in the direction of research during the process, but programmes do not take into account the complexity of implementing the solution and the frequent need for cooperation. Representatives of companies in our survey emphasise that, in the case of projects financed from public funds, it is very difficult to change the project assumptions during the process and call for greater trust – 'Entrepreneurs should be given more flexibility and the right to make mistakes as this is what searching for innovative and effective solutions is about' [Interview ORG-01].

However, there are promising results among some innovative support programmes aimed at accelerating cooperation between innovative startups and big companies in more mature industries. These have been introduced by the Polish Agency for Entrepreneurship Development (PARP) in partnership with technological parks (i.e. the PARP KPT ScaleUp accelerator). With the low level of industry 4.0 implementation in Polish companies, technology parks become an essential channel for transferring state-of-the-art solutions. It is hard to assume that incubators and technology parks will be a central pillar for introducing Industry 4.0 solutions among Polish producers, but they can be an important element in the upgrading of Polish industry. Know-how in the area of particular unsolved problems is critical to the success of initiatives along with support for global expansion.

Another example of good practice could be clusters (e.g. Automotive Silesia, the East Automotive Alliance). The role of a cluster is to support cooperation, spread knowledge and provide the opportunity to attract potential suppliers. A representative of one of our organisations [Interview ORG-01] pointed out that (especially foreign) executives increasingly expect companies to have a range of competences – from design through to the ability to make a prototype and to develop an implementation-ready solution. In this context, cooperation between companies is crucial because most local firms are too small to carry out this kind of imperative alone.

4. Conclusion – the thorny road to Industry 4.0?

Polish automotive suppliers, especially SME companies, are at the very beginning of the path leading to the implementation of Industry 4.0 solutions. There is a growing awareness among owners and managers, but few companies have yet started to taste the waters and, for now, the thorough implementation of smart manufacturing in the automotive industry is limited to large foreign-owned plants.

At the moment, in automotive suppliers with predominantly Polish capital we can observe pilot implementations of Industry 4.0 solutions. The companies that are experimenting with these are mainly seeking a means of better serving their existing customers; very rarely are they embracing Industry 4.0 as a long-term strategy aimed at upgrading to a higher level in the value chain. Thus, the argument that digital transformation facilitates the independent internationalisation of local SMEs and their integration into global value chains can not be confirmed at the current stage of development of the bulk of companies in the automotive industry in Poland. There are only a handful of companies that are consciously introducing a strategy of full implementation of Industry 4.0. However, a more adequate concept describing such companies would be 'readiness for change towards 4.0;' there is a strategy to reach 4.0 based on a high sense of advance (the implementation of comprehensive Industry 3.0 solutions), preparing staff and seeking the availability of capital. Even so, the vast majority of domestic suppliers are at the transition stage from Industry 2.0 to 3.0 solutions. A specific feature of Polish suppliers is still a significant amount of production by manual labour, especially in companies founded in the 1990s. Undoubtedly, the acceleration of the implementation of solutions in the field of automation and robotics production at the level currently observed in Polish industry will be a vehicle that will also accelerate the implementation of Industry 4.0. However, this will be an incremental upgrading because there are no mechanisms that allow leapfrogging. The interviews we conducted indicate that, at the current stage in the automotive industry in Poland, companies are mostly interested in Industry 4.0 solutions in the area of predictive maintenance.

The application of Industry 4.0 solutions in the coming years will not be a factor likely to improve significantly the position of Polish automotive suppliers in European production networks. In a perspective of a few years alone, neither will it have a negative impact on their functioning in the market. This is connected on the one hand with the inertia of industry (the duration of contracts already concluded) and, on the other, with the existence of cost and product niches in which local producers may remain competitive. However, if the technology gap continues, this will represent a serious threat to the competitiveness of these companies in the medium and long-term.

The main barriers to the development of Industry 4.0 are the underfunding of technological innovations; intellectual barriers among owners and managers; and a lack of skilled staff (both among production workers and among management). Moreover, the lack of cooperation between companies, research centres and government is having negative effects on the development of innovations (cf. Table 2). Our research also shows a deeper problem resulting from the characteristics of organisational culture and social capital in Poland. As one of the managers pointed out: 'The plants operating in Poland are focused solely on production, not on data interpretation. Polish SMEs have not mentally reached the stage "Measure the process and improve it"' [Interview COMP-01]. Another interviewee remarked: 'We have an inadequate organisational culture in Poland. The basic barrier is low trust among companies and a low degree of cross-linkages' [Interview COMP-01].

Support instruments introduced by the Polish government aimed at accelerating and facilitating the transition of the Polish economy into Industry 4.0 are of a very recent nature (the first actions were taken in 2018). Therefore, it is too early to draw a firm conclusion about the effects of the newly-implemented programmes. The public stakeholders we interviewed are also careful in their opinions, stressing that public support should not be overestimated in the whole process of speeding toward Industry 4.0 in Poland. Nevertheless, managers assess the activities of the Ministry of Enterprise and Technology as valuable, mainly in the field of providing support for education and staff training. What is considered by managers as particularly relevant and effective in terms of support is the possibility of experimenting and exploring new fields. Without public financial support, Polish companies could not afford this. There have been some promising results among some innovative support programmes aimed at accelerating cooperation between innovative startups and big companies in more mature industries which have been introduced by the Polish Agency for Entrepreneurship Development (PARP) in partnership with technological parks and Special Economic Zones. The major long-term positive effect of current policies may be found in networking activities among business companies, research centres, universities and other institutions.

Four main factors that have, or could have, an impact on accelerating the implementation of Industry 4.0 solutions in the Polish automotive industry have been identified. The most important, according to this survey, is the growing cost and decreasing availability of employees. Support offered by public authorities could become an important factor but, because the leading tool (the Platform for Future Industry 4.0) is at the implementation stage, it is difficult to indicate how effective it will be. It should be remembered that a large number of countries have implemented similar mechanisms, so it is difficult to predict *ex ante* the extent to which the activities of the Polish institutions will be effective. Given the structural features of Poland (low institutional social capital), one should be careful in forecasting that it will be a breakthrough factor. Another vehicle for the implementation of Industry 4.0 solutions might be customer policies, primarily among OEM and tier one companies towards their tier two and lower level suppliers. This path, however, is associated with the danger of increased dependence on the dominant partner.

The growth of Industry 4.0 in Poland may depend not only on the production companies themselves but also on the development of domestic companies specialising in the integration of automatic and digital solutions ('digital entrepreneurs'). Technological changes related to Industry 4.0 seem to provide a window of opportunity for medium-sized Polish suppliers of tailor-made technological and software solutions. These are providers of comprehensive services in the field of industrial automation, PLC programming, robotics, SCADA visualisation systems, MES class systems, industrial informatics, data collection and archiving. Thus, we predict that the upgrading of companies with Polish capital will be more indirectly than directly related to the development of Industry 4.0 in the automotive industry. The large cluster of automotive companies in central Europe creates a market for domestic companies offering Industry 4.0 solutions which can build their competence on the basis of cost and responsiveness factors. The relatively large size of the domestic market facilitates the implementation of what are ground-breaking solutions for innovative SME companies.

On the other hand, the massive size of the internal market reduces the pressure on companies to 'go global' and take on challenges abroad. Also, the relatively close headquarters-coordinated structures of foreign-owned subsidiaries hamper any moving-up in the newcomer value chain. The key to the upgrading of domestic companies is the engagement of Polish tech companies in developing digital solutions which would make many indigenous firms experience a 'leapfrog effect'. However, according to some experts, 'Due to the lack of expertise in automation and robotics in Poland, foreign suppliers will be able to profit more than others from the trend towards automation' (https://industryeurope.com/polish-automation-gaining-momentum/).

Thus, we may conclude that, at the current stage of research, although the domestic market has significant limitations (low demand from local companies and limited decision-making competence among foreign subsidiaries), it does offer some important growth factors for digital entrepreneurs. This point was well summarised by one of our interviewees: 'The level of global OEMs is beyond our reach at present. But between them and small companies there is a vast space for growth' [Interview COMP-01].

Taking into account the preliminary conclusions resulting from this exploratory research among high-tech domestic companies which are providers of Industry 4.0 solutions, a promising research agenda is emerging which could aim, *inter alia*, at the identification of the growth factors appropriate to such companies and in-depth investigation of the conditions for the promotion of competence within European and global value-added chains. Future research might also explore the functioning of the ecosystem for high-tech domestic 'digital entrepreneurs'; the main mechanisms and factors behind the upgrading of these companies; and the impact of regional and local features on their emergence and growth, in particular the extent to which geographic proximity – both to customers and to other high-flying domestic companies – is important for the development of such firms.

Appendix

List of interviewed companies and organisations

Interview No	Type of company	Main activity/products	Turnover in PLN millions (M)* Employment**
COMP-01	Digital entrepreneur	Control and automation systems	PLN 10-20M 100 employees
COMP-02	Digital entrepreneur	Provider of industrial automation and industry 4.0 solutions	PLN 10-20M 50 employees
COMP-03	Digital entrepreneur	Provider of automation, IT solutions and industrial robotics for different branch of industry, inluding automotive	PLN 50-100M 60 employees
COMP-04	Automotive supplier Tier 1 / Tier 2	Design & testing services for automotive industry, special machines-design and production, Conversion of vehicles from combustion engine to electric drive	PLN 50-100M 400 employees
COMP-05	Digital entrepreneur	Design of vehicles, modules and parts for the transport industry (including automotive)	PLN 50-100M 250 employees
COMP-06	Digital entrepreneur	Design and manufacturing of 3D scanners for the automotive industry	PLN 10-20M 50 employees
COMP-07	Automotive supplier Tier 1	gas springs, ball joints and tie rods	PLN 10-50M 250 employees
COMP-08	Automotive supplier Tier 2	plastic components for automotive, electrical enginnering, home appliances and interior decoration industry	PLN 50-100M 150 employees
COMP-09	Automotive supplier Tier 2	Stamped metal parts	PLN 100-200M 250 employees
COMP-10	Digital entrepreneur	Factory automation and processing technologies, drive products, computerised numerical controllers	PLN 100-200M 250 employees
COMP-11	Automotive supplier Tier 2	Rubber products, plymers and elastomers combined with metal and plastics for the automotive, household appliances and electrical enginnering industries	PLN 5-10 M 50 employees
COMP-12	Automotive supplier Tier 1	Starter batteries	PLN 200-500M 200 employees
ORG-01	Business Organisation	Association of manufacturers of automotive parts and accessories.	Over 20 members (1-2 bln of revenues and 5000 employees in 2017 in total)
ORG-02	Business Organisation	Support for the ecosystem of high-tech companies: technology incubator and accelerator, certified Living Lab, providers of hardware, software and network infrastructure	PLN 10-50M 50 employees

* Euro (EUR) to Polish zloty (PLN) annual average exchange equalled 4,298 in 2019.
** Employment figures do not include agency or temporary workers.

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Chapter 6
Digital entrepreneurs in factory economies: Evidence from the automotive industry in Hungary

Andrea Szalavetz

1. Introduction

Digital entrepreneurs[1] are perceived as being innovative in the Schumpeterian (1934) sense. Their offerings rely on, embody or are embodied in digital technologies (Lyytinen *et al.* 2016) that are bringing about a multiplicity of new product-service combinations and revolutionising the patterns of value-adding activities. Consequently, digital entrepreneurs are considered to have a transformative impact. Their activities disrupt some industries, rendering them obsolete, create new ones and transform the business practices and models of actors in related industries (Vial 2019). Note that, since digital technologies are general purpose ones, practically all industries are 'related'.

Digital entrepreneurial ventures have a large potential impact not only in a technological sense but also in an economic one: their high growth potential is demonstrated by the rapidly-growing number of business unicorns based on digital technologies.[2] Given this double impact, it is no surprise that digital entrepreneurship is currently deemed of paramount importance to economic development (Nambisan *et al.* 2019).

Digitalisation is expected to herald a new era in entrepreneurship (Nambisan 2017), not only in advanced economies, although the development benefits of digital technologies are not evenly distributed (World Bank 2016). Yet, digital entrepreneurship may become a new, qualitative source of economic growth, intensifying the catching-up of countries that are prepared to exploit the much-praised capacity of digital technologies, namely that they 'democratise innovation and entrepreneurship' (e.g. Aldrich 2014; Nambisan 2017).[3]

However, in line with the scholarship which posits that not all entrepreneurs are equal (e.g. Henrekson and Sanandaji 2019; Lafuente *et al.* 2019) and, furthermore, that there are non-negligible differences among digital entrepreneurs themselves (e.g. Sussan and Ács 2017; von Briel *et al.* 2018), it is essential to explore the features of digital entrepreneurs outside the centres of digital technology production. Uncovering the differences between advanced economies and less developed ones in the features and prospects of digital entrepreneurs may extend our understanding of the differences in the potential of these agents to become levers of growth and upgrading.

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1. Digital entrepreneurs are considered in this chapter in the narrow sense of 'digital technology entrepreneurs' (Giones and Brem 2017).

2. 'Unicorns' denote companies valued at $1bn or more: https://www.cbinsights.com/research-unicorn-companies.

3. For a review and a comprehensive critique of this view, see Dy (2019).

Complementing a large body of studies focusing on the nature and implications of digital entrepreneurship in advanced and in high-performing emerging economies (e.g. China), there is an emerging literature analysing the features and the practices of digital entrepreneurs in economic peripheries, in particular in Africa (e.g. Graham 2019).

By contrast, there is scarce empirical evidence on the specifics of digital entrepreneurs in central and eastern European dependent market economies (CEE).[4]

The purpose of this chapter is to address this gap by drawing on insights gathered from interviews with twelve Hungarian digital entrepreneurs operating in the automotive technology ecosystem. We analyse the particularities of digital entrepreneurs in CEE; that is, whether the surveyed companies display the features described in the academic literature on digital entrepreneurs. This allows for a consideration of the impact of digital entrepreneurship on the dependent position of the region; specifically, whether these important agents of innovation represent a strategic opportunity to shift CEE economies to a relatively higher-road trajectory of economic development. Can digital entrepreneurs enable these countries to break out of the dependent model?

The rest of this chapter is structured as follows. The introductory section is followed by a brief review of the literature on the specific features of digital entrepreneurs. Subsequently, the method of empirical data collection is outlined and the empirical findings presented. The final section discusses the findings and concludes with some propositions regarding the ways of interpreting and improving the developmental outcomes of these particular species of companies.

2. Digital entrepreneurs: a particular species driving high-road development

Digital entrepreneurship is defined as the setting up of entrepreneurial ventures with offerings (products, services or product-service systems) that embody, or are embodied in or enabled by, digital technologies (Lyytinen *et al.* 2016). Prior research associates digital technology-based new ventures with knowledge-intensive, Schumpeterian entrepreneurship, and postulates that these companies have a high growth potential (Henrekson and Sanandaji 2019; Huang *et al.* 2017; Lassen *et al.* 2018). The activity of digital entrepreneurs is expected to bring about meaningful economic gains in terms of innovation, productivity, growth and employment (Lafuente *et al.* 2019).

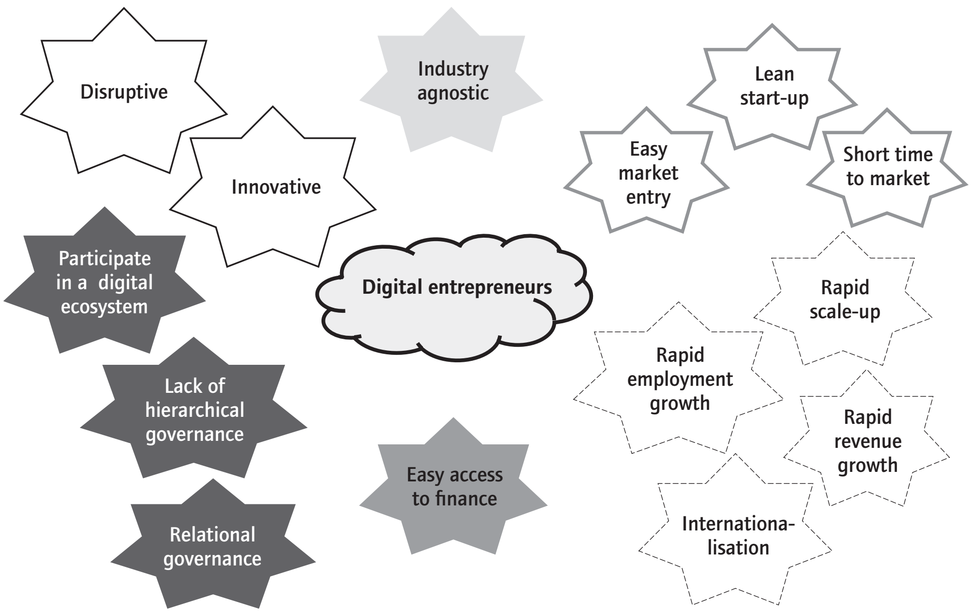
Scholarly analyses list a number of additional distinctive characteristics that apply to digital entrepreneurs (Figure 1).

Besides the two most common catchwords (Schumpeterian and disruptive) referring to their innovativeness, important distinctive features of digital entrepreneurs include a

4. A notable exception is Skala (2019). See also a companion paper prepared in the framework of this project (Szalavetz 2020).

'lean start-up' mode of market entry[5] (Blank 2013; Ries 2011) and a higher than average speed of scaling-up (Autio and Cao 2019; Huang *et al*. 2017). In Nambisan's (2017: 1035) wording, digital technologies allow entrepreneurial processes to 'unfold in a *non-linear fashion across time and space*' (italics added).

Figure 1 **Characteristics of digital entrepreneurs**



Source: author's compilation based on her survey of the literature

Since digital technologies allow for low-cost experimentation with entrepreneurial ideas, entry barriers are lower and market entry is easier while the time to market is shorter for digital than for conventional entrepreneurs (Autio and Cao 2019; Nambisan 2017).

Digital entrepreneurs' rapid internationalisation is facilitated by digital technologies themselves. Digital infrastructures and platforms bridge distance and enable larger than average market reach. Moreover, if the number and needs of users or customers escalate, these can be met without adding proportionately more resources (Zhang *et al*. 2015). Consequently, the value created and appropriated by entrepreneurs can grow rapidly – this is referred to by Nambisan (2017) as the non-linearity of digital entrepreneurs' growth.

Scaling-up is also enabled by digital entrepreneurs' relatively easy access to finance. It is claimed that digital entrepreneurs are able to overcome resource constraints and

5. Instead of entering the market with a product deemed 'perfect', as a result of large-scale upfront development, lean start-ups would launch 'minimum viable products' or offerings that are intentionally incomplete (Nambisan 2017), relying on customers' feedback for further development.

obtain funding for their expansion relatively easily, for two reasons: firstly, because they are able to harness digital technologies that reduce the information asymmetries which hinder conventional lending processes (Estrin *et al.* 2018); and, secondly, because they are major beneficiaries of the intensifying interest of 'BigTech' companies (the best capitalised, largest technology companies) in financial services provision (Frost *et al.* 2019), and/or are recipients of corporate venture capital investment by large, established, non-digital firms trying to integrate digital offerings in their core products.[6]

Digital entrepreneurs are considered industry agnostic (Autio and Cao 2019), targeting customers in virtually any sector. This substantiates the claim that digitalisation has transformed the nature and degree of openness in innovation and entrepreneurship (Nambisan *et al.* 2019). Compared to conventional start-ups, it is easier for digital entrepreneurs to acquire large established companies as customers, since these latter need to adapt to the 'digitalisation imperative' to streamline their operations, improve their processes and create new business models (Crittenden *et al.* 2019). Additionally, digital entrepreneurs can benefit from strong public incentives supporting their growth, among others by subsidies for the adoption of new digital solutions.

Over and above being integrated in particular value chains, the business environment for digital entrepreneurs can rather be described as a digital ecosystem, i.e. a network of interdependent and collaborating organisations that use digital infrastructure to create value jointly (Sussan and Ács 2017; Valdez-de-Leon 2019).

Another noteworthy feature characterising digital entrepreneurs is that their inter-organisational exchanges are characterised either by *relational governance* based on trust, collaborative problem solving and information sharing (Gereffi *et al.* 2005); or by *ecosystem governance* in which the rules of participation and the distribution of revenues among the partners are clearly established.[7] Compared to the captive or hierarchical governance modes characterising the transactions of physical product suppliers or manufacturing subsidiaries in factory economies, this feature suggests that local digital entrepreneurs rely on a high level of technological knowledge for their integration in global value chains and that their contribution involves knowledge-intensive, high value-adding activities.

3. Research design, data collection and analysis

Since digital entrepreneurship by domestic-owned actors in factory economies is a nearly uncharted territory of academic research (Szerb *et al.* 2018), this chapter employs an exploratory research design, based on corporate interviews, to obtain insights on the ways digital entrepreneurs exploit the specifics of cyber technologies (Eisenhardt 1989).

6. For example, Sandler (2017) provides a survey of the top venture capital investment providers in the automotive technology sector and shows that there are several established OEMs among them.
7. Being embedded in digital ecosystems, i.e. in loose networks of digitally connected and interacting organisations *that are not managed by a hierarchical authority* (Valdez-de-Leon 2019), characterises an increasing number of digital entrepreneurs.

Articles in the business press and reports by management consultancy firms abound in success stories describing the evolution of some highly-valued digital empires. Although the Global Unicorn Club contains barely any companies from peripheral factory economies,[8] local observers, also in 'low/moderate performer' dependent market economies, find it relatively easy to identify a couple of local high-flying, entrepreneurial companies specialised in today's paradigm-changing, digital technologies.

The context of this study is Hungary, a typical dependent market economy (Farkas 2011, 2016) in which both innovation performance (European Innovation Scoreboard 2018) and business digitalisation performance are particularly weak.[9]

The sample was selected on the basis of two criteria. The selected companies were: (1) domestic-owned entrepreneurial ventures specialised in the provision of digital solutions; and (2) involved in supplying automotive companies. The context of one single industry, the digital automotive technology ecosystem, was selected in an effort to homogenise the sample – at least partially. The automotive industry proved to be a good choice, since the digital intensity of value-adding activities is among the highest in automotive value chains (Calvino *et al*. 2018). Furthermore, given Hungary's strong specialisation in this industry[10] and the dominance of foreign-owned manufacturing units, this industry accordingly exemplifies Hungary's dependent market economy status and its exposure to developments in the automotive industry and to the strategic decisions of lead companies.

The method of purposeful sampling (Patton 1990) has been applied and companies whose cases seemed promisingly information-rich were chosen. This was made possible by the author's database of a collection of business press and technology press articles describing the achievements of Hungarian companies in terms of digital transformation and digital innovation.[11]

Twelve domestic-owned entrepreneurial ventures were interviewed between January and April 2019. Interviews lasted 90 minutes on average and were guided by an interview protocol consisting mainly of open-ended questions to facilitate exploration. The questions were organised around three topics: the history of the venture; its business strategy; and the factors enabling its integration in highly- concentrated automotive value chains.

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8. In August 2019 the 'Club' had 393 members, with US and Chinese unicorns accounting for the dominant majority of listed companies. The new member states of the European Union were represented by one firm from Estonia and one from Malta.

9. According to the business digitalisation pillar of the composite Digital Economy and Society Index, Hungary scores the second lowest in the EU-28, ahead only of Romania (DESI 2018). Hungary's position in international rankings of entrepreneurial capabilities is also much lower than those of its CEE counterparts (Hungary was 50th in the 2018 edition of the Global Entrepreneurship and Development Index; in contrast, Poland was 30th, Slovakia 36th and the Czech Republic 38th (Ács *et al*. 2018: 28-29).

10. This industry accounted for more than a quarter (27.1 per cent) of total manufacturing production in 2018 (source: author's calculation from Central Statistical Office data).

11. See companion paper (Szalavetz 2020) for details.

The empirical data obtained during the interviews have been analysed in two pieces of work. The main focus of this book chapter is the specifics of the surveyed firms, their offerings and their business strategy; while a companion paper (Szalavetz 2020) is concerned with the factors enabling the integration of digital solution providers in automotive value chains.

The qualitative data obtained from individual interviews have been analysed content-wise, involving the identification of the key commonalities that facilitate interpretation. Analysis was conducted using standard within-case and cross-case analysis techniques (Eisenhardt 1989). We applied the constant comparative method for data analysis (Glaser 1965), collecting and analysing data simultaneously. This allowed us to cross-check the emerging patterns in subsequent interviews and/or contrast interviewees' remarks with those gained in prior interviews.

4. Results

To set the context, we first asked about the specifics of the surveyed firm's products and/or solutions. We asked our interviewees to recount the history and how their offerings had been developed. The interviews had been preceded by the compilation of secondary source data (press releases and business press articles about the company, public profit and loss accounts and notes to the financial statement). These documents disclosed important basic data on the firms in question and were useful also in terms of triangulating interview information. The basic data of the surveyed firms are summarised in Table 1.

The detailed descriptions in Table 1 highlight that the offerings of the sample companies show great diversity, reflecting the multiplicity of entrepreneurial opportunities stemming from conceivable product-service combinations. Notwithstanding this diversity, some commonalities allowed for the classification of our sample companies into two groups. Based on the accounts of the interviewees, we have grouped the solutions of the surveyed firms into a 2x2 matrix according to hardware/software intensity and the customer specificity of the given solution (Figure 2). Hardware-intensity is obviously considered in a relative sense since the solutions of all companies are highly software-intensive or, in a broader sense, intangibles- and knowledge-intensive.

Figure 2 reflects that the distribution of the sample is skewed, since the dominant majority of the companies create and deliver custom-tailored digital solutions (industrial cyber-physical product-service systems). These technology providers integrate digital technologies in customers' production/business systems to enhance the efficiency of, and the value of the data generated by, customers' production/business processes. By contrast, the companies in the bottom left quadrant (BLQ) offer productised (rapidly scalable) digital solutions.

Table 1 **Overview of sample firm characteristics (data for 2018)**

No.	Product	€	Employment	Year of foundation	Interviewee
1	A self-driving software stack. A simulation solution for testing autonomous vehicles (the purpose-built virtual representation of the environment, allowing the recreation of problems in vehicles' environments so that simulation and validation exercises can be carried out). A power-efficient hardware IP core to accelerate the deployment of artificial intelligence-based self-driving software that solves the problems associated with the current excessively high power consumption of the hardware that accelerates AI-based automated driving solutions. A highway autopilot solution for autonomous highway driving.	~5m	182*	2015	Marketing officer
2	Business intelligence: provision of big data, data visualisation and analytics-based solutions of company-specific problems; strategic consulting relying on data science approaches.	9.5m	136	2006	Communications officer
3	Connected car vehicle-to-everything (V2X) solutions: a software stack allowing for V2X communications to be integrated in on-board units or roadside units.	~1m	29	2012	Technology officer
4	Integrated digital ergonomics system, i.e. a motion digitising and evaluating device that captures, measures, records and analyses data related to assembly workers' motion, to be used for ergonomic analyses and testing.	~7k	4	2014	Managing director
5	Engineering services: ** development and implementation of production tracking systems, barcode and RFID solutions for production logistics and warehousing, self-developed real-time location system.	3.9m	31	1990	Business unit manager
6	Engineering services:** development and implementation of visual inspection solutions (camera-based or 3D scanning-based) for quality control in manufacturing production; industrial software development e.g. traceability systems and MES.	766k	10	2015	Founder
7	Immersive virtual reality system, i.e. a 3D educational and virtual collaboration platform to be used (among others) by students specialised in automotive engineering or to be applied for training new employees in automotive companies. Furthermore, this platform integrates various online collaborative tools connecting multiple users: used for example in new product development.	101k	2	2013	Founder
8	Development, manufacturing, deployment and commissioning of custom-tailored production machinery combined with smart solutions. Analysis and solution of specific technological problems related to customers' product and process development and engineering activities. R&D in the field of simulation methods and finite element analysis.	7.1m	51	2002	Founder

No.	Product	€	Employment	Year of foundation	Interviewee
9	Engineering services:** development and deployment of cyber-physical production systems (CPPS), robotic systems integration, development of CPPS-based functional solutions (e.g. quality control, process automation, production monitoring and optimisation, etc.). R&D on collaborative robots and the development of demonstration use cases for collaborative robots.	5.5m	46	1991	Business development manager
10	Conceptual design and implementation of customised special purpose machinery for factory automation; systems integration services (robotics, computer vision, measurement systems, data acquisition and processing).	508k	14	2012	Founder
11	Design and implementation of cyber-physical systems and analytics solutions for manufacturing companies. Consultancy about the ways and methods of digital transformation and implementation of smart factory solutions. Data-driven and AI-powered business process re-engineering and optimisation, solution of technological problems.	67k	2	2013	Founder
12	Industrial Internet of Things (IIoT) platform for smart factories, based on big data technologies and machine learning. The platform is capable of implementing machine learning-powered process optimisation. The platform supports smart factory applications. Design and implementation of smart factory solutions on the basis of this platform.	~25k	10	2017	Founder

€ = net sales in EUR (the exchange rate used for conversion from HUF was 319); k = thousand, m = million, employment = number of employees, MES = manufacturing execution system.
* In addition to 182 employees in Hungary, the company has dozens of employees abroad.
** Engineering services include assessment of the customer's processes; identification of bottlenecks; conceptual design of a solution; procurement, deployment, installation (commissioning) and, in some cases, the servicing and maintenance of system-specific hardware e.g. machinery or track and tracing infrastructure, cameras, sensors or other data capture tools, user interfaces and other system components; together with the development and deployment of the related software e.g. reporting algorithms, mobile applications and system integration services.

Figure 2 **The classification of sample companies' products & solutions**

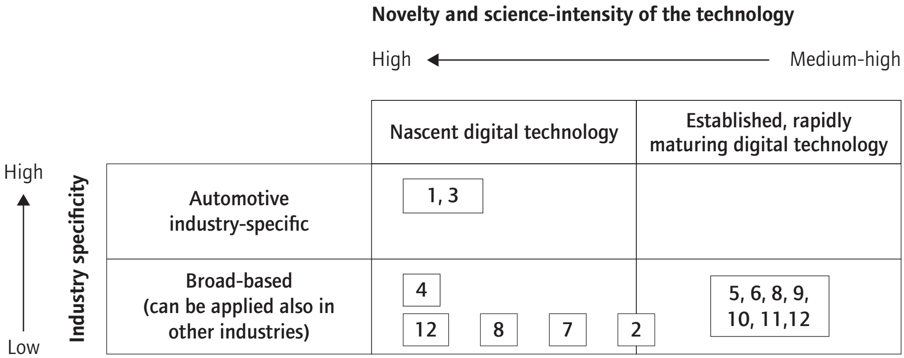
	Productised solutions	Custom-tailored digital solutions
Hardware-intensive		**4, 5, 6, 8, 9, 10**
Software-intensive	**1, 3, 7**	**2, 11, 12**

Source: elaborated by the author, based on information from the interviews

Although it is challenging even for technical experts to determine the technological novelty of specific solutions, in order to guide our analysis we have grouped the solutions of the surveyed firms also according to the novelty of the technology (Figure 3). In categorising individual solutions, we relied both on the opinion of the managers interviewed and the concepts of technological novelty outlined in the literature.[12]

On the one hand, Figure 3 confirms the claim that (most) digital entrepreneurs are industry agnostic: their solutions can be used by customers in any sector (Autio and Cao 2019). The customer portfolios of most of the surveyed firms are not limited to automotive industry actors; nevertheless, automotive companies represent a large share of their customers. This demonstrates the pioneering status of the automotive industry in the field of digital transformation.

Figure 3 **Some additional features of sample companies' products & solutions**[13]



Source: elaborated by the author, based on information from the interviews

On the other hand, Figure 3 also suggests that the offerings of the majority of firms in the sample are neither disruptive nor radical innovations based on nascent technology. The solutions of firms in the bottom right quadrant (BRQ) of the matrix rely on already-existing, and rapidly maturing, digital technologies, e.g. cyber-physical systems, factory

12. In order to determine novelty, Abernathy and Clark (1985), for example, analyse the capacity of an innovation to influence the established production system and customer base, classifying innovations as incremental or radical. Radical innovations make existing production systems obsolete, destroy the value of existing expertise, demand new procedures and/or create new markets. In a similar vein, Tushman and Anderson (1986) classify technologies as competence-enhancing or competence-destroying – the latter is characterised by a higher degree of novelty. Other scholars in the innovation literature rely on concepts of (a) technological uncertainty, e.g. regarding the means to accomplish certain tasks (e.g. Fleming 2001); or (b) familiarity and previous experience with the product and process technologies employed to create the desired new product or solution. In this latter sense, Henderson and Clark (1990) consider a technological invention radically new if, compared to existing technologies/solutions, it is based on different scientific and engineering principles.

13. Companies 8 and 12 are represented in multiple quadrants. This refers to different products/activities. For example, besides designing and implementing custom-tailored and smart solutions embedded in special machinery, No. 8 is also engaged in the solution of product development-related technical problems and conducts basic research to develop material science-specific simulation methods – used by global automotive companies aiming at reducing the weight of selected components. No. 12 is specialised in basic research-intensive IIoT development, which is represented in the bottom left quadrant of the matrix. Additionally, however, it designs and implements industry 4.0 projects for Hungary-based manufacturing companies (mainly automotive ones). This latter activity is classified in the bottom right quadrant of the matrix. Note that custom-tailored individual solutions of companies in the bottom right quadrant are highly heterogeneous also in terms of the technological and R&D capabilities required to design and implement the given solution.

automation, simulations, digital twins and analytics. These technologies are applied in company-specific combinations and enable adopters' digital transformation to achieve improvements in their existing production systems and/or solve particular technological or business problems.

Irrespective of the deployment of smart factory-specific digital technologies requiring extensive software development and systems integration capabilities, these solutions no longer convey *nascent* technologies. Smart factory-specific or 'industry 4.0' solutions are becoming more and more mature and established. Considering that the term 'industry 4.0' was officially introduced less than a decade ago, in 2011, at the Hannover trade show, this reflects the acceleration of technology innovation cycles.

As the following interview excerpt demonstrates, the entrepreneurial strategies and practices of BRQ companies have not changed, they have simply *grown digital*.

> 'The activities we perform have not changed radically; we simply integrated digital technologies both in our activities and in our offerings.' (No. 5, 6, 9)

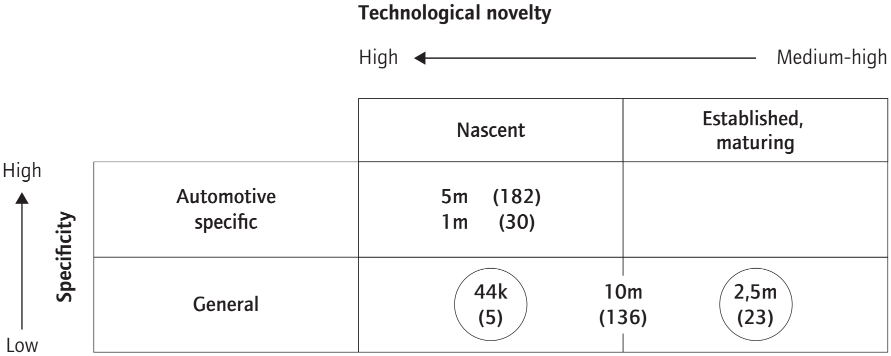
Notwithstanding that these offerings have no 'transformative' impact, i.e. they are not expected to bring about creative destruction, they are evidently innovative in a Schumpeterian sense, representing 'new product-service combinations' and/or 'reform[ing] or revolutioni[sing] the pattern of production by exploiting […] an untried technological possibility for producing […] existing commodities in a new way' (Schumpeter 1943: 132).

In contrast, the offerings of companies in the 'nascent technology' column can be regarded as radical novelties. Interview data confirm that these *born digital* companies introduced their offerings in the market as lean enterprise-specific, incomplete, 'minimum viable products' (Ries 2011). The solutions of this group of companies are at different stages of R&D and commercialisation, and all have undergone continuous evolution ever since the first versions were introduced. Although the managers interviewed (No. 1, 3, 4, 7 and 12) have all underscored that their offerings require several years of further development, the 'still incomplete' products of these companies are generating, in some cases, revenues that are already non-negligible.

Investigating the association between the novelty of the technology and business performance, our data indicate that there is no meaningful relationship between these variables (Figure 4). For example, although the offerings of companies in the BLQ of the matrix (No. 4, 7 and 12 – the IIoT platform in this latter case) represent radical novelty, the impact of these companies in terms of revenues is lower than that of companies in the BRQ.[14]

14. Note that a simple comparison of turnover data without considering the cost of goods sold may provide a distorted picture. This item may be quite large in the case of companies supplying smart factory solutions together with systems integration services since it may include purchased special purpose machinery.

Figure 4 **Turnover and employment in sample companies**



Note: data in circles are averages for respective groups
Source: elaborated by the author, based on information from the interviews

More importantly, the growth performance of nascent technology companies does not unambiguously validate the assumption that digital entrepreneurial ventures have a high growth potential. The level of 'adequate' performance in terms of revenues can barely be determined in the case of nascent technology companies, whose offerings represent radical novelty, while it is also hard to fathom how long it takes to reach the tipping point after which sales performance 'explodes' – this is highly heterogeneous across digital entrepreneurs. Nevertheless, it is clear that the turnover data of companies 4, 7 and 12 (this latter is a very young company) leave a lot to be desired.[15]

One reason for their failure to scale is that they have not been able to overcome the usual financial constraints faced by entrepreneurs. Although several companies obtained either venture capital investment or research grants, the managers interviewed considered the low level of external funding as one of their main obstacles to growth.

Companies 1, 2 and 3 are the only ones to represent a textbook case of Schumpeterian, high-impact, rapidly-growing digital entrepreneurs specialised in nascent technology and offering born-global products.

As for entrepreneurs specialised in hard-to-scale, custom-tailored digital solutions, the main determinant of growth is, in principle, their business development capability. However, as the following interview excerpt illustrates, business development was not an issue for companies in the right-hand column of Figure 2 since demand for their offerings was growing rapidly.

> 'There is such a high demand for our specialised expertise in digital engineering services provision that we do not have to make substantial investments in business development – we have more assignments than what we can reliably accomplish.' (No. 8)

15. This finding is consistent with the literature on business gazelles and high-impact firms (e.g. Ács 2011), positing that the average high-impact firm is not a new start-up.

Nevertheless, neither have these companies experienced rapid growth: in their cases, growth has been rather moderate, albeit sustained. The main bottleneck limiting growth in this latter group is the lack of skilled software developers and engineers, exacerbated by fierce competition for talent both from the better-capitalised local subsidiaries of global companies and from foreign labour markets.

The employment data of companies in the sample also seem disappointing, especially in the light of the literature emphasising the strong positive impact of entrepreneurship on job creation (see survey in Haltiwanger *et al.* 2013). The companies in the sample had, on average, been operating for ten years in 2019; even so, only two of them have more than 100 employees. The average number of employees is 43 across the sample and, without the two outliers, it is only twenty.[16]

Interviews reveal that the market orientation of the surveyed firms is closely related to the specifics of their offerings. The providers of production-related digital services or product-service systems have not internationalised:[17] they have remained local, targeting Hungary-based manufacturing firms that were, in most cases, the local subsidiaries of global companies.[18] Companies 2 and 4, and those in the BLQ of Figure 2 offering productised solutions, are predominantly export-oriented. Some of the exporting companies have even established sales offices in Silicon Valley and in emerging Asian economies.

Regarding the governance modes characterising the transactions of the surveyed companies, our interview information confirms the prevalence of relational governance. Relational governance is justified in cases where the planning and implementation of custom-tailored digital solutions require close collaboration between technology providers and adopters. This collaboration is based on trust and the sharing of knowledge between the two parties. Solution provision is not a one-off activity: the technology providers demonstrate their capabilities, build trust and accumulate knowledge about customers' problems in the course of the initial projects. Subsequent assignments by the same contractors are usually broader and deeper. Another explanatory factor of the prevailing mode of governance is the uniqueness of knowledge, precluding price-based competition and hierarchical governance.

> 'It's a kind of joint experimentation with our main customer to improve our offering further. It is not a market-based transaction where price matters.' (No. 4)

> 'It is not the price of our services that matters. What matters is achieving the trust of prospective customers so that they believe in our capabilities, that we can solve

16. Note that, instead of hiring new employees, several small companies (with fewer than ten employees) would, from time to time, resort to independent contractors (freelance software developers) providing software development services to accomplish specific projects. They would do so because orders were volatile. Consequently, company-level employment data do not precisely reflect the real employment impact of these ventures.
17. This finding is consistent with the Polish experience; see the chapter in this book by Gwosdz *et al.* (2020).
18. Company No. 2 is an exception: it offers business intelligence services, supporting business management rather than solving production-related technological problems. Its customers are mainly international, including some Fortune 500 companies.

their problems.' (No. 2); '[It's not the price of our services but] what matters is being involved in internationally-funded research projects.' (No. 9)

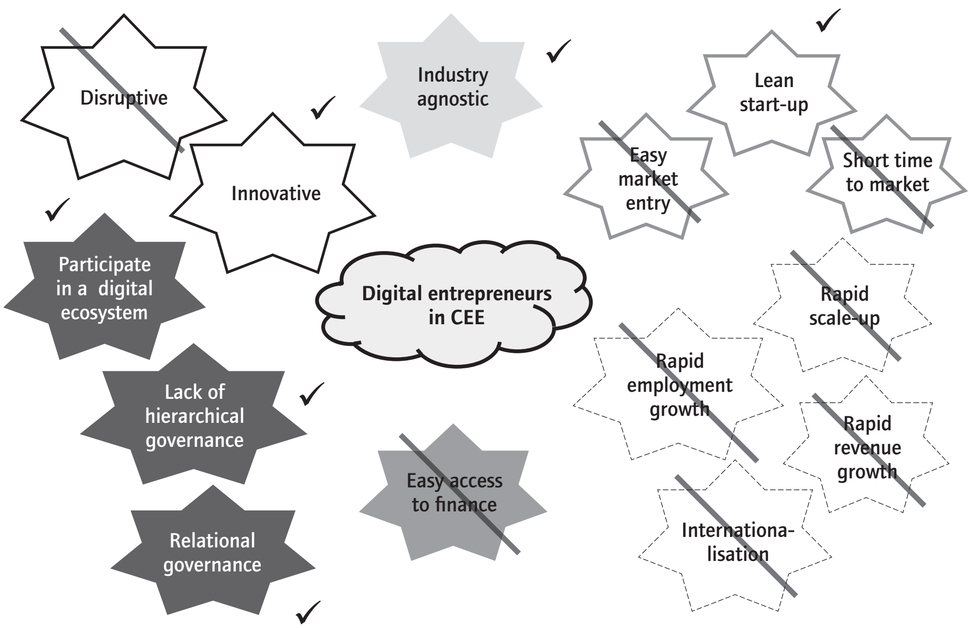
Ecosystem governance was relevant in the cases of two companies in the sample (No. 1 and 3) and, occasionally (i.e. in some projects), also for Nos. 8, 9 and 12.

'We collaborate with our future customers in a number of research and demonstration projects funded by foreign stakeholders, research funds, local municipalities or EU-programmes. A non-negligible share of our revenues stems from these collaborations. You see, our competitiveness is based on the reputation we have built so far. Our [ecosystem] partners *trust* that we are able to contribute.' (Nos. 1 and 3)

5. Discussion and policy implications

From these results, we can conclude that the specifics of the surveyed digital entrepreneurs do not fully and unambiguously conform to those described in the literature (Figure 5).

Figure 5 **Results**



Source: elaborated by the author, based on information from the interviews

Indeed, the offerings of most of the surveyed companies prove to be industry agnostic while the governance mode characterising their transactions is relational or ecosystem-based, not hierarchical. Half of the firms in the sample have, indeed, introduced 'still incomplete' products, to be further developed according to customers' feedback, which confirmed the lean enterprise-specific mode of digital entrepreneurs' market entry. On the other hand, the custom-tailored solutions offered by the other half of the sample have also attained ready-to-launch form following an iterative process of joint fine-tuning by teams in both the vendor and the customer. In that sense, the examples of the surveyed firms would all confirm the 'lean start-up' feature characterising digital entrepreneurs.

However, although the companies in the sample are all innovative in a Schumpeterian sense, their offerings were disruptive in few cases. Instead of a 'transformative impact', the solutions of companies in the right-hand column of Figure 2 have enabled adopters to perform their traditional core activities more efficiently than previously.

Instead of explosive growth, most companies have experienced only a more or less modest increase in revenues and employment. For most, access to finance has proven to be one of the key obstacles to scaling-up.

Furthermore, contrary to the alleged rapid internationalisation of digital entrepreneurs, the majority of the surveyed companies – those in the BRQ of Figure 3 – have remained local.

Most of the differences we identified are related to the specifics of the offerings. Note that companies with productised offerings were under-represented in the sample while the providers of customised digital solutions for manufacturing plants were over-represented. Further research is required to determine whether the distribution of digital entrepreneurs is significantly different in dependent market economies from that of advanced economies, i.e. in terms of a higher than average share of entrepreneurs offering production-related digital solutions to the local manufacturing subsidiaries of global companies. Intuition suggests that this is the case; however, the small size of the sample does not allow for general conclusions in this respect.

From another perspective, it is obvious that, in a country where innovation and business digitalisation performance are weak, and labour productivity and entrepreneurial performance low, all kinds of digital entrepreneurs matter – not only the high-impact ones that display explosive growth. Whether their products are disruptive or not, digital entrepreneurs play a crucial role in improving these performance indicators. They contribute to the upgrading of local technology, since the adoption of digital technologies improves adopters' productivity and competitiveness. Consequently, all kinds of digital entrepreneurs – not only high-growth ventures with disruptive offerings based on radical innovation – can assist dependent market economies' efforts to progress towards a high-road trajectory of economic development. The surveyed companies should be acknowledged as drivers of productivity- and innovation-driven, high local value-added, qualitative development.

Nevertheless, in the dependent market economies of CEE, the extent to which digital entrepreneurs generate economic gains for their countries of origin is dwarfed by that of efficiency-seeking foreign direct investment in export-oriented manufacturing. For example, the performance of even some high-flying companies in the sample appears insignificant in comparison with that of traditional automotive subsidiaries.[19]

Altogether, local digital entrepreneurs are, currently, barely able to improve the dependent position of CEE economies: their number and economic impact are too small to bring about the required qualitative shift in the development trajectories of these countries. Digital entrepreneurship could become a statistically more significant source of GDP growth only where two conditions are fulfilled. On the one hand, a critical mass of digital entrepreneurs is indispensable: their number needs to increase rapidly. On the other, digital entrepreneurs need to be able to access the inputs necessary for their growth in terms of finance, business development know-how and adequately skilled labour.

Our results call for a fostering of digital entrepreneurship, as an avenue to qualitative economic development and upgrading. This demands no radical policy innovations: traditional policy instruments[20] are required, promoting the accumulation of digital competencies and subsidising investments that increase companies' digital maturity. This latter promises to kill two birds with one stone: in addition to improving technology adopters' total factor productivity, it also offers new business opportunities to local digital entrepreneurs.

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19. In 2018, the turnover of Magyar Suzuki was higher than that of No. 3 by a factor of 2,000, and that of a relatively smaller local automotive subsidiary, Hankook Tire, by a factor of 700. (Source: author's calculation from data of the Top 50 Hungarian non-financial companies, HVG, 25th July 2019.)

20. At the same time, the experiences of the surveyed companies also call for new policy mechanisms, e.g. accelerator programmes that foster the scaling-up and the internationalisation of digital ventures offering productised solutions.

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Impact on workers

Chapter 7
Technological and organisational innovation under Industry 4.0 – Impact on working conditions in the Italian automotive supply sector

Matteo Gaddi

1. Introduction: research aims and summary of the impact on working conditions of current technologies

This chapter focuses on the main technological and organisational changes that are taking place in automotive supply companies located in Italy and the consequences these are having for working conditions.

As suppliers of parts and components to original equipment manufacturers (OEMs), these companies form part of a series of production networks which transcend national borders. The linkage with OEMs plays a decisive role, especially from the point of view of just-in-time supply practices: in this sense, organisational models (Lean Production extended throughout a fragmented production chain) as well as new technologies (Industry 4.0) are being implemented simultaneously to ensure close coordination and synchronisation within the entire production chain. Specifically, this encompasses: a) planning of production processes; b) transmission of production orders; and c) control of the progress of production in order to meet delivery dates. Furthermore, the organisation of work (i.e. working time and rhythms, workloads, etc.) is almost entirely determined by the needs of the OEMs which are requiring their suppliers to adopt particular organisational and technological tools.

At the same time, automotive supply companies located in Italy are subject to competitive pressure from companies in countries with low labour costs. Or, rather, it is the OEMs themselves who are creating this type of competition in order to lower their supply costs, putting western plants in a position of competing with plants in low labour cost countries. This is resulting in the adoption of production models by plants located in Italy based on seeking to maximise profitability through sizable increases in productivity, achieved through a particular organisation of work facilitated by applications of new technology.

These issues – and specifically the connection between Lean Production and Industry 4.0 – are playing an important role in the development of the working conditions of employees in supply companies. Explicitly, the result is a general intensification of work through a significant increase in the degree of exploitation of the workforce.

In Italy, the National Industry Plan 4.0, which has provided strong tax incentives for companies to make investments in 4.0 technologies and presented by the Italian government in 2016, was received with great enthusiasm by the larger part of public opinion, as well as by the majority of business organisations, political parties, etc.

The research programme of Fondazione Claudio Sabattini has been aimed towards developing an understanding of the specific consequences that these innovations are having for working conditions. This chapter presents the main results of our findings as regards the automotive supply sector.

Our research questions are related to:

— the interweaving of Industry 4.0 technologies and Lean Production models (Butollo *et al.* 2018; Sanders *et al.* 2016; Sony 2018; Wagner *et al.* 2017);
— the type of technologies, especially in information and communications technologies (ICT), that companies in this sector are implementing (Otzemel *et al.* 2018; Qin *et al.* 2016; Thoben *et al.* 2016; Brettel *et al.* 2014; Tzafestas 2018);
— what consequences these technological and organisational innovations are having for working conditions from the perspective of: work cadences and rhythms; workloads; work content; human-machine relationships; and control over the performance of work.

From the point of view of the influence on working conditions, the main results that our research has highlighted can be set out as follows.

The companies involved in our research are paying general, and serious, attention to investments in ICT. Enterprise resource planning (ERP), manufacturing execution systems (MES) and internet-based forms of connectivity are widespread and being used for the management of all aspects related to: a) the planning of activities; b) relations between suppliers and customers; c) the planning and scheduling of different stages in the production process; and d) monitoring and control.

There is no lack of investment in fixed capital (machinery, robots, plant, etc.); rather, there is a new wave of automation underway in which the greater share of investment is in products and services characterised by connectivity and ICT capabilities. Under these investments, and within the Industry 4.0 process as a whole, companies have the objective of increasing productivity with consequences for employment that are not likely to translate in the near future into redundancies and lay-offs (at least, not mass redundancies), but rather into no expansion of the workforce even though production volumes may be increasing.

Companies' aims here are being made possible by technologies which are able to trace the beginning and the end of each single task: data relating to all operations within the production process can be recorded, collected and monitored thanks to computer systems. Furthermore, machines and plants are generating a quantity of data related both to volumes produced, the phases carried out and the processing of each batch and any problems that are limiting functionality and causing downtime (breakdowns, setting-up, controls, lack of materials, etc.). In the case of manufacturing operations, ICT tools – more specifically, the apps which are established within them – achieve this by reading barcodes connected to work orders via optical readers, personal tablets and on-board PCs embedded within a machine or a line. The barcodes indicate the work order being performed, the machines and components used and the production process being carried out, and associate it with the ID of a particular operator. All the data obtained are immediately uploaded to the company's information system servers via ERP or MES, and made visible in real time to the offices responsible for control and monitoring, while the MES communicates work orders directly back to each workstation.

A count of the exact time taken by a particular task is thereby commenced in which a company is able to develop a clear and precisely detailed understanding of the time taken up by the work cycle – but, of course, not only that one: the ability to record time does not only affect individual task operations but the entire production cycle (right from the acquisition of orders to the delivery of product). These cycle times are incorporated into work orders defined by engineering departments by means of the ERP software that plans the production and defines the scheduling. Indeed, a strict definition of working time is, therefore, a prerequisite for the true coordination of the various production phases.

In this way, a cycle time can be imposed within which an operator must conclude each particular task, taking it away from the knowledge and control of workers while, at the same time, allowing real-time and remote control over work performance. The constraint on workers can therefore be understood as the obligation to adapt their work rhythms and cadences to cycle times, not only concerning the speed at which a semi-finished product moves between work phases but right the way across each single phase within the production process as a whole.

Thus, these technological investments possess a clear labour-saving character: i.e. companies are benefiting from the ability to do more with less. This increase in productivity has occurred mainly under an intensification of work cadences and a marked reduction in the time assigned to machine operators for each task/operation within the wider production process. In consequence, the level of 'saturation', i.e. the ratio between shift working time and the quantity of work actually done during that shift, is deteriorating significantly. Working times are becoming, in many cases, extremely difficult for workers to meet, due also to the high degree of variability in workloads and production mixes (Gaddi 2018, Gaddi 2019).

This intensification of workloads (and the saturation of the work process) has, in our view, at least three causes: a) operations carried out by workers are often complementary and subordinate to those carried out by machines (since workers are conditioned by the cycle time of the machine); b) under the pretext of automating the toughest tasks, workers are now in charge of operating more than one machine at the same time; and c) workers are in charge of a number of operations – self-checking, quality control, etc. – which were previously the responsibility of others. In the context of (a), we should note in addition that the worker is becoming forced to act as a mere appendix of the machine while, furthermore, the ready appearance of data on performance in control and monitoring offices – which may be located elsewhere and even internationally – is an additional source of pressure within the workplace.

Through these control systems, companies are able to compare internal costs with prices from external suppliers: in this way, companies are able to achieve more objectives: to calculate production costs; to calculate the cost of each worker; and to decide whether or not to outsource a certain production phase. In this way, competition between 'internal' and 'external' workers is also being created, which also adds to the pressures being put on employees.

To try to conceal these negative effects of a more highly saturated work process, companies are attempting to portray work cycle times as in some way 'objective', or possessed of a scientific quality determined by the technology, instead of them appearing for what they are, i.e. the social decisions of companies. This means, moreover, that they are being hidden from the perceptions of workers and, thereby, removed from formal and informal negotiation.

The same things are occurring with the use of dispatch tools in the field of maintenance/assistance/repair, etc. By combining the use of scheduling software with devices (tablets, smartphones, etc.), operators are being provided with a list of maintenance/assistance interventions to be carried out, including the time to be spent on them and with the aggravating circumstance that workers' locations are also being recorded and controlled by the technology.

Neither is office work exempt from these operations: in addition to the classic mechanisms for recording the start and end of operations, software is capable of tracking the various 'clicked' functions and of checking for any errors, overlaps or repetitions, activities which have no added value, etc.

For these reasons, our contention is that Industry 4.0 technologies, in guaranteeing the minute traceability of each single operation and its progress status, are facilitating the real-time extraction of information which allows the pervasive and real-time control of the performance of each employee. We believe, therefore, that Industry 4.0 technologies are fulfilling the so-far incomplete manufacturing revolution developed under Lean Production; and that it is the coming together of both which is having the most deleterious consequences for working conditions. The 'brilliant factory' is just that: a powerful device for controlling workers.

This chapter is organised as follows. Following this brief introduction and summary of theme, section 2 summarises the application of Lean Production models and Industry 4.0 technologies within the sector. Section 3 introduces some essential characteristics of the contemporary Italian automotive sector; and then goes on to document the field research carried out by the Fondazione Claudio Sabattini, with a series of case studies used specifically to illustrate various themes on the influence that these models and technologies are having on the shape of the sector and on working conditions within it. Finally, section 4 provides some conclusions.

2. Applications of Lean Production and Industry 4.0

Lean Production, of which the production system in Toyota is the foundation, aims to increase productivity by eliminating waste, resulting in a tightly controlled production flow in which all elements, including suppliers, are strictly synchronised. Overproduction (anything which is not necessary for the following production stage) is seen as waste and should be eliminated while waiting times need to be minimised. Lead times are compared with production times, eliminating synchronisation errors, material delays, sudden queues, failures, lack of operators, tooling times, etc.

Meanwhile, Industry 4.0 factories are 'smart' ones in which a set of technologies - communication tools, connectivity, data collection and processing - allows to connect work tools,equipments, plants, and products so that they can communicate directly with each other and with centralized systems, at such a speed that they can do so continuously and in real time: the increase in the computerization of manufacturing systems and the use of network and ICT technologies allows to integrate and synchronize all parts of the system in an information network (Forschungsunion 2013; European Parliament 2016).

Industry 4.0 technologies are, therefore, a perfect match for the objectives of Lean Production: digital technologies can play a decisive role in shortening waiting times and contributing to a reduction in plant reset times.

Lean Production systems and Industry 4.0 technologies are used widely in automotive production, both by car manufacturers and suppliers – the latter often being compelled by the former to introduce them. In both cases, this is translating into a heavy intensification of the pace of work and of workers' performance.

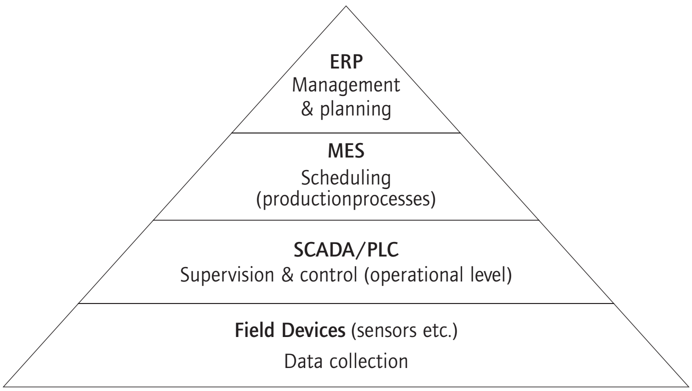
Our research has shown that applications of Lean Production and Industry 4.0 technologies are closely connected, even sharing the same 'philosophy'. In our opinion, Industry 4.0 is not fully understandable unless we also take into account that close relationship with Lean Production. In particular, Industry 4.0 technologies facilitate the full implementation of Lean Production, overcoming the technical constraints that previously limited its application. Furthermore, it is the intertwining of these two elements that is having the most critical consequences for working conditions.

Essentially, Lean Production implies the passage from a 'push' to a 'pull' logic: whereas formerly production planning was 'pushed' by sales forecasts, now it is being 'pulled' by customer orders – i.e. from another company, or even from another department within the same one. Thus, it is orders which trigger the entire production chain. One of the pillars of Lean Production is just-in-time: if the entire production process is 'pulled' by customer orders, nothing must be produced upstream that is not required downstream. Each piece must be produced at the time a downstream workstation requests it through *kanban*: the visual instruments which transmit information and instructions on the materials to be supplied by storage areas – 'picking *kanban*' – and the components to be produced – 'production *kanban*'. New technologies, when applied to the *kanban* system, enable the strict synchronisation of different production phases and the management of departmental and workstation demand in real time. The entire process can be constantly monitored from the screen of any connected device.

OEMs control their suppliers even though the latter are formally responsible for their own internal processes. This translates into OEMs having a substantial degree of control over work performance.

The attached figure highlights the typical integration architecture adopted by companies in the automotive sector in Italy – the so-called 'pyramid of automation'. The first level in this architecture is represented by enterprise resource planning, which constitutes a set of planning tools for order acquisition and processing, supply chain management, the management of human resources and the production capacity of plants, production engineering, etc. The second level is the manufacturing execution system, which performs scheduling functions, the dispatch of production orders, resource allocation, product and workforce tracking, performance analysis, production reporting, etc. The MES, starting from the general process planning generated by the ERP, deals more specifically with its scheduling and with the dispatch of production orders to each department and/or workstation. Subsequent operational levels are based on SCADA (Supervisory Control and Data Acquisition, which monitors and supervises machinery and devices on the factory floor), as well as technologies such as PLCs (Programmable Logic Controllers contained on single pieces of machinery or plant) or other, similar, tools and apps. The final level is represented by sensors and other data collection tools in the field.

Figure 1 **Automation pyramid**



Industry 4.0 technologies allow the (vertical) integration (or vertical networking) of this architecture, reducing the number of steps between decisions and system control and, hence, flattening the pyramid.

In fact, Industry 4.0 combines the digitalisation of manufacturing processes with real-time data acquisition, processed and analysed via server and edge (cloud) computing as a means of optimising industrial processes (Akerman 2018; Rojko 2017).

The whole process is started with a Data Acquisition Module, facilitating the statistical analysis of the data that has been acquired. The different nodes of the network (products, machinery, controllers, etc.) exchange information through technologies developed through IoT (Internet of Things) applications. The data acquired in this way are processed not only by cloud computing and Big Data analytics, but are also used by CPSs – Cyber Physical Systems, i.e. virtual simulation tools for physical processes. Thereafter, feedback is transmitted to PLCs, the MES and ERP to make production not only flexible but also highly reconfigurable, and the latter within a very short timescale.

This means that planning, scheduling, work order dispatch and plant operation can be continuously redefined – compelling the workforce to adapt continuously. Integration of all levels within CPS facilitates close cooperation between all departments and individual phases. In this just-in-time environment, increases in productivity are based on the strong intensification of work performance, i.e. a greater degree of labour exploitation.

This system connects the entire production cycle right from the end to the very beginning: i.e. backwards from the end of the assembly line – the point at which a customer's production orders can be dispatched to that customer – one stage after another, workstation after workstation. From the point of view of Lean Production, this eliminates overproduction (components are supplied in the exact number in which they are required) and minimises waiting times (components get to each station at the exact moment required, and without loss of time).

Industry 4.0 technologies also provide crucial support for the full implementation of the logic of *kanban*, deployments of which are becoming progressively electronic and which make sending, receiving, recording, etc. both easier and faster. Starting from general production planning via ERP, and hence from production scheduling by times and workstations via MES, electronic *kanbans* can be generated and transmitted to connected devices embedded within each workstation. When the requests of a *kanban* have been met, the electronic recording system shows the progress in order to allow management to monitor it in real time and step in immediately when synchronisation adjustments are needed.

Respect for assigned times is central to Lean Production, in which the pace of production is determined by 'takt time' – the time taken up by the production of one unit of a specific output. Industry 4.0 technologies allow the real-time monitoring of takt times through connected recording devices which immediately upload data to company information systems which compare actual and planned times. In this way, takt time determines working times across all lines and at each workstation, imposing rhythms and working systems to meet the standards set by the company. They also facilitate the levelling of workstation saturation, or *heijunka*: once takt times are defined, workloads to be allocated to the various workstations are computed automatically, taking into account the availability of facilities and staff.

Strict adherence to takt time and the obsession of Lean systems with reducing lead times means that tools which are presented as aids for workers – in carrying out their assigned tasks, they do not have to 'waste time' in thinking, checking, verifying, etc. – or otherwise as ways of reducing operator anxiety about possible errors are thereby transformed into tools for intensifying work performance. The implications of *poka-yoke* ('foolproof') systems, which provide detailed instructions to each workstation, or automatically assign combinations of batch-machine-component codes, renders workers less and less autonomous: MES communicates with all the connected machines and guides workers through the various operations, indicating the components to be used and the sequence of operations to be carried out.

The integration between Lean Production and Industry 4.0 is also very important in terms of logistics: lines are automatically supplied by electronic *kanbans*, with products delivered both to the warehouse as well as to external suppliers via the same software tools and computer systems. In this case, the provision of everything needed for production directly to workstations, far from being an aid to the operator, constitutes yet another way to cancel any form of 'waste' in terms of 'non value added activities'. This classification of activities into 'value added' and 'non value added' (NVAA) is another critical element of Lean Production – the former being the only activities that, in progressively transforming inputs, add value to them. In contrast, non value added activities do not directly add value to inputs and must, therefore, be compressed as far as possible since they are viewed as 'downtime'. NVAAs usually include all such activities connected with arranging/predisposing, searching, placing, pushing, pulling, dividing, cleaning, walking, all types of waiting, all types of stoppages, measuring, counting, controlling, sending/transferring, etc.

World Class Manufacturing (WCM) is an evolution of Lean Production and is also strongly integrated with Industry 4.0: under this approach, all operational activities and production support must be continuously improved in order to generate a flow of value added without waste and with the fewest possible losses. In other words, workers must strive for a workflow that takes place at maximum speed and at minimum cost.

WCM defines waste as leakages of value due to some kind of overproduction (stocks awaiting processing, defective parts, plants stopped as a result of failure rates, etc.); while losses are the cost of not allocating a resource to its optimal alternative use, measured as the loss of value added associated with such a misallocation – an economist would call these 'opportunity costs'. A worker awaiting instructions, materials, equipment, the restart of an idle machine, etc. generates not only a waste but also a loss because the waiting time could, alternatively, be used to carry out activities that produce value added.

WCM assigns special importance to so-called Total Preventive Maintenance (TPM): production workers have to keep their workstations clean and tidy, perform daily maintenance of machines and equipment, etc. – all of which are non value added activities in the WCM logic. In other words, companies are assigning to production workers those activities which were previously carried out by maintenance workers. This meets a two-fold objective: a) to saturate production workers as far as possible;

and b) to ensure the correct and continuous operation of plants within the logic of a tightly-controlled flow of production.

Actual operating times depend on faults, settings, adjustments, etc., the resolution of which increases the rate of utilisation of plants as well as their performance and the quality of the final product. These three factors together – rate of utilisation, performance and product quality – determine the overall equipment effectiveness (OEE) i.e. the total efficiency of the plant. Industry 4.0 technologies allow OEE to be computed in real time and data to be transmitted to the offices which are in charge of monitoring and control. Improving these indicators also has enormous consequences for workers in terms of the monitoring of performance, the intensification of working time and the introduction of bonuses related to actual performance.

As in all Lean systems, therefore, identifying and eliminating NVAAs is crucial to WCM and its technical pillars: ‘cost deployment’; ‘focused improvement’; ‘autonomous maintenance’; and ‘workplace organisation’. In particular, the cost deployment pillar takes place in each area, identifying the losses and wastes inherent in all manufacturing processes and sub-processes, quantifying them in terms of cost and defining action programmes aimed at their reduction. For example, the cost associated with NVAAs is the number of minutes taken up by workers engaged in such activities and multiplied by their wage per minute – thus identifying these as a cost to be cut.

WCM introduces distinctions between resulting losses, which can be observed, and causal losses, the latter being the origin of the former. Total costs, therefore, can be traced back by identifying the resulting losses and summing up the corresponding causal losses. For example, a worker performing NVAAs implies lost production – which, in turn, is associated with fixed costs, the depreciation of investment items, energy costs, etc. – but also in terms of keeping downstream workers waiting: i.e. lengthening lead times and desaturating the work process, etc.

The precise quantification of all these cost items is why each workstation is required to be equipped with on-board connective devices (sensors, monitors, optical readers, etc.) capable of recording and transmitting any imperfections, irregularities or diversions of the flow. In this way, it is possible to single out any potentially disposable NVAA, which now takes on a very broad definition based on the causal chain of all the resulting losses and wastes. This is also what allows the allocation of workloads and cycle times to be presented as entirely ‘scientific’, as the result of the software processing of variables that are, by definition, objectively measured. This puts companies into a coveted and advantageous position since, where these are not questionable, this makes formal and informal negotiation on workloads, labour organisation and staffing levels increasingly hard to achieve.

3. The field research: Italian companies in the automotive supply sector

3.1 The shape of the automotive supply sector

In order to understand the practical impact of Lean Production and Industry 4.0, it is necessary to explore briefly the contemporary shape of the sector.

We should stress that the Italian automotive industry is undergoing a process of transformation characterised by an absolute drop in the production of vehicles (from 1998 to 2018: the number of vehicles produced dropped by 1.3m), accompanied by a relative rise in the production of parts and components. This implies a significant change in the structure of employment. In 1998, forty per cent of employment was devoted to parts and components and 52 per cent to final (vehicle) production; but, by 2018, these proportions had been reversed, to 53 per cent and 41 per cent respectively.

Italy is, in some respects, moving towards a production specialisation similar to that of some central and east European countries which specialise in the supply of components to western (mainly German) car manufacturers. However, Italy is characterised by higher wages, which raises doubts about the permanence of this kind of production model. In fact, two models of supply are emerging: that of countries with low labour costs (Poland, Czechia, Slovakia and Hungary), characterised by state funding and investment incentives, located close to Germany and at the service of German OEMs; and that of western countries in which the production of parts and components is still inextricably linked to the national manufacturers who absorb it. However, the disappearance of a national carmaker in Italy makes the situation in this country increasingly uncertain: if Fiat Chrysler Automobile's production volumes are too low to absorb the parts and components produced in Italy by multinational companies, these could make drastic decisions about their Italian sites, preferring those located in other countries with lower labour costs and closer geographical proximity to final sites of assembly. Component manufacturers located in Italy are, therefore, increasingly re-orienting their production to supply foreign, in particular German and French, car manufacturers.

Furthermore, it is clear that supplier companies are being conditioned by two aspects: a subordinate position in the production chain; and competition with companies in the low-cost countries of central and eastern Europe.

As supplier companies, their production conditions are significantly determined by the OEMs which have the power to decide costs, timing and conditions. For example, they must continuously provide just-in-time supplies to OEMs, with rigid planning and scheduling of their own production processes and a strict synchronisation of internal production with both their customer(s) and their own suppliers.

Moreover, in facing up to competition from low-cost countries, they will try both to reduce production costs further, with negative consequences for wage levels; and to increase labour productivity, with negative consequences for working conditions as regards the intensification of performance, the reduction of assigned cycle times and increases in workload saturation.

Industry 4.0 technologies and Lean Production models are the main elements that are determining working conditions in the automotive supply sector. In the next section, we highlight the close interweaving of these two elements. It should be stressed that these two elements are being applied not only at the level of an individual company, but throughout the supply chain as a whole.

3.2 Outline of the research

To highlight what is being determined by the technological and organisational transformations that we have described above, we have examined several companies operating in Italy in the automotive supply sector (see Appendix for details):

— Midac (Verona) – battery manufacturer and a tier one supplier;
— Fiamm Hitachi (Verona) – also a battery manufacturer and a tier one supplier;
— Cebi Motors (Padua) – a manufacturer of micro-motors and gearmotors, and a tier two supplier;
— Fonderie Montorso (Vicenza) – a castings manufacturer and tier three supplier;
— Magneti Marelli (Corbetta, Milan) – a manufacturer of dashboards, inverters and control units, and a tier one supplier;
— ST Microelectronics – a semiconductor manufacturer and tier one supplier.

In each company, a series of interviews were carried out with workers from different departments in order to develop our views on how the entire production cycle is being affected by these transformations. The plants involved in the research are all unionized. The interviews involved full-time union officials, shop stewards, and even simple workers who are members of Fiom Cgil (metalworkers' union). The research, in fact, was carried out in collaboration with Fiom Cgil, which is interested in understanding the spread of Industria 4.0 in the industrial metalworking sectors and its consequences on working conditions. For each plant, in-depth interviews were carried out (from a minimum of 5 to a maximum of 15) with the figures mentioned above, each lasting about one hour. Subsequently, further analyses were carried out through the analysis of: the companies' Industrial Plans, the investments made and planned, the layouts of the production departments (plants, machinery, lines). The analysis of these documents was followed by further in-depth analysis through interviews. A draft-report was prepared for each plant and sent to full-time union officials and shop stewards so that it could be discussed collectively (a sort of Focus Group) and then supplemented with further information and details that emerged during these meetings. At some plants it was also possible to visit the production departments, depending on whether or not the company management were willing to authorise this possibility. Interviews and factory visits took place in the second half of 2018 and during 2019.

Thus the approach to the research questions is qualitative.

In the rest of this section, analysis of our field material has been organised as follows: first of all (in section 3.3), suppliers' relationships with their client companies have been studied to highlight how the latter's role is decisive in determining production conditions; and then the knock-on effects of this on the network of supply companies that the suppliers have, in turn, created (since they, too, have decentralised significant parts of their production). We then focus on internal conditions in the plants from the point of view of the role played by planning and scheduling tools in determining production processes and workloads (section 3.4); and the impact these have in terms of working conditions in production lines and departments (section 3.5). The latter highlights, from our examples, that the tools of Lean Production and Industry 4.0 technologies are responsible for the deterioration in working conditions.

3.3 Case studies in supplier relations

This sub-section demonstrates how OEM suppliers closely control their own suppliers, creating a complex and closely integrated production network the boundaries of which may also extend internationally. Supplier companies seek to build very close relationships within their supply network in order closely to synchronise all steps. Obviously, this close level of synchronisation and control over supply conditions heavily affects the working conditions of workers in companies in the subsequent links in the chain.

The fragmentation of production is facilitated by tools that allow the continuous transmission of production orders, even several times a day (forcing workers in decentralised companies to speed up and become more flexible to meet these work orders) and, at the same time, to monitor how the supplier company is working (in respect of assigned times, production progress, etc.).

Thus, the relationship with the companies to which they are a supplier is a central preoccupation for companies in the supply chain: customers may impose on them the application both of organisational innovations (models of Lean Production, thus extended to the entire production chain) and choices of technological systems. We should recall here that, in the Lean Production mindset, it is the final customer – i.e. the OEM car manufacturer – that pulls the whole chain, in the process determining working conditions in all the downstream links. Companies in the automotive supply chain must therefore operate according to the same just-in-time principles and systems dictated by those to which they supply. Industry 4.0 made it possible to establish the main principles of work organisation (i.e. Lean Production model) throughout the entire supply chain.

In our case studies, Industry 4.0 is operating in the direction of horizontal integration:[1] i.e. the integration of different factories belonging to the same production chain. The main Industry 4.0 technologies used for this purpose are: ERP extended to the whole

1. As opposed to vertical integration, i.e. the integration of different functions within the same factory.

chain; production order transmission tools; electronic data interchange tools (EDI) for document sharing; and production progress monitoring tools (MES). Our case studies show that the intensification of work performance and of control over it is the direct consequence of the decisions of the car manufacturers whose demands supplier companies cannot afford to ignore otherwise they would lose supply contracts. This applies throughout the process, including tier one, tier two and tier three suppliers, and beyond. The model facilitates a substantial reduction in the possibility of trade unions to negotiate working conditions: everything is presented as fixed since it is dictated by the requirements of the customer.

Case studies: OEMs and tier one suppliers

Magneti Marelli (MM) – within its plant at Corbetta, Milan – produces dashboards, control units, inverters, etc. for manufacturers from other countries such as Germany (Porsche, Audi and Volkswagen). The way in which the car manufacturers submit their orders, and the time allotted to Magneti Marelli for supply, have a very significant impact on the organisation of work and on working conditions.

For instance, Porsche has adopted a 'herringbone' production model: the customer can configure an online order, customising the choice of car. This order is managed by a central information system which requires all the actors involved in the delivery chain to be synchronised. The MM Corbetta plant periodically receives production orders through an EDI tool called Value Added Network (a hosted service offering secure data transmission between partners). Just five days before the assembly of the car in Germany, Magneti Marelli receives an order via VAN to start production on exactly the sequence of on-board instruments which must be assembled in the Porsche plant to meet the order. Porsche's orders, therefore, have a daily character and Magneti Marelli's production process (and hence its workers) must adapt to them.

Another example of the closeness of tier one suppliers to OEMs can be found among the battery manufacturers. In order to meet the significant levels of coordination dictated by the just-in-time principle, planning and production phases in both Fiamm and Midac must be carefully synchronised, defined and implemented on a just-in-time basis. Battery charging programmes depend strictly on customer orders: the battery is charged only when it has to leave the factory otherwise it risks a loss of charge. This aspect obliges OEMs to provide themselves with a logistical service amongst its suppliers that is functional to production and just-in-time delivery. No delay, in fact, can be allowed: the time allotted must be strictly adhered to.

Case study: tier two suppliers

Cebi is a tier two supplier; in this way, it is subject to double pressure: the first is that from the OEM; while the second is that from the tier one supplier.

In Cebi, the acquisition of customer orders is carried out by ICT. The tier one supplier is Brose (a German firm), which now accounts for eighty per cent of Cebi's production and for which Cebi is the only supplier. Brose makes a call based on its daily needs and transmits this order to Cebi automatically via an EDI tool; this allows Brose to provide a daily frequency of orders and Cebi to verify the stocks and the quantities of materials which must be allocated to that customer. Cebi, in fact, operates with a deposit account at a customer plant (Consignement Stock), from which it withdraws materials daily according to its production needs. In this way, Cebi's system works on the basis of daily flows, updating the stock requirements and planning the production needed to rebuild stock at the German plant. Through this way of managing customer orders, the organisation of production at Cebi is modulated according to Brose's requests.

In general, the management system at Brose continually processes the flow of orders that it receives from car manufacturers before turning them over as orders to Cebi. The role of the tier one supplier can be particularly invasive: here, Brose demands that, every four hours, Cebi production operators fill in a control card in connection with the amount of production they have realised. This data is monitored both by the internal offices in Cebi and by Brose itself.

Case study: use of new technologies and organisation of the supplier network amongst tier two suppliers

Cebi is itself digitally connected with some of its suppliers. In this way, Cebi's suppliers, before shipping materials, can provide data notifications concerning each job and the control parameters which apply (already performed and self-certified by the supplier in question). This system allows materials to arrive directly on Cebi's production lines which, based on a 'free pass' model, saves testing time while also facilitating data collection.

Cebi's programming department develops data with the aid of material requirements planning (MRP) software and sends out its supply plans on this basis. The lead time for suppliers do differ: from China it is one month; while from local network suppliers is daily: for this reason some of them having machines and processes dedicated to Cebi and which work in a continuous cycle. Supplies from faraway low-cost countries represent an element of system fragility whose effects are passed on to Cebi's workers who have to deal with any delays by working overtime or on Saturdays (or even during holidays).

Case study: use of new technologies and organisation of the supplier network amongst tier three suppliers

In the case of Fonderie di Montorso, 'core' suppliers directly receive orders generated by the management software, together with a technical data sheet detailing the specifications and the cycle times which must be observed. The relationship with subcontractors is based on special methods of control by FM through the use of computer tools. By virtue of its control system, FM can outsource many stages in the production process. The management system developed by FM comprises a SAP dashboard with an ERP tool which allows the integration of external contractors in the system.

The subcontractors therefore have their own workstations equipped with PCs on which are installed the web dashboard that interfaces with the company system; in this way, production status is displayed directly. The system was developed and supplied by FM, together with the technology and training (made by FM technicians).

FM can therefore control – in real time – the production feeds of its suppliers and also verify that they are complying with the production plan.

3.4 Impact on workers: planning and scheduling of work orders

We have seen that planning and scheduling tools constitute fundamental elements in the automation architecture aimed at maximising the productivity of the entire production process.

Once orders are acquired, they are immediately processed via ICT tools (ERP) to define production programmes. The latter, in turn, are immediately scheduled (via MES) to define the individual work orders which are transmitted to each workstation. In this way, companies are able to remove from collective bargaining both the overall production volumes (and the question of the corresponding numbers of workers needed to deal with them) and the workloads assigned to each worker. It must always be remembered that the work orders transmitted to each worker have already been defined from the point of view of the time assigned (and which is, in turn, getting tighter and tighter as a result of competition).

The purpose of the companies here is, as we have highlighted, to 'objectify' the assigned workloads and working times so as to make them indisputable. Regardless of the state of technological progress, the consequences for working conditions, both in terms of the intensification of pace and control of the process, are very similar.

How process planning/scheduling translates into work orders (workloads) and performance control

MM uses TESAR's tools, such as MOTIS1 and MOTIS2, amounting to an integrated system for planning and controlling production. These work thanks to real-time data collection terminals directly connected to production machines. MOTIS1 constitutes software for the planning and scheduling of industrial production: it optimises the workloads of machines and workers as well as the performance and productivity of the entire company. MOTIS2 is the software for production management, data collection and monitoring (MES): this allows for the control and management of the production process, considering both the declarations of operations performed and the automatic monitoring of the production parameters of any machine/plant. Moreover, the interactive management of these declarations feeds a complete and powerful system of real-time supervision, statistics, indicators and reports.

Through these items of software, production is not only programmed but also scheduled as regards the assignments for each operator and the equipment required to carry out the workload within each shift on the basis of acquired orders, relative priorities, availability of materials and plant, etc. In this way, the organisation of production is rigidly determined, with little room either for the autonomy of workers or for bargaining over workloads. For MM, it is also decisive that this planning/scheduling of activities is continuously monitored, thus introducing forms of control over the performance of work.

In the lines dedicated to the production of dashboards, daily production plans are indicated on work orders bearing job codes which also correspond to the operating programs of the machines and the types and quantities of products to be manufactured. Components to be inserted on electronic circuit boards are also indicated by the production plan; once they have been 'called' digitally, the pick-and-place machine is automatically activated to place the boards correctly. During the day, the production program may vary, requiring the resetting of the entire line to be done in the shortest possible time. All these operations are recorded. The planning of activities and their recording are two closely intertwined aspects of the organisation of work, whose integration is facilitated by the ICT tools available. In MM, the application of WCM techniques has also resulted in pressure to reduce downtime.

In STM, Industry 4.0 is being implemented as a means of guaranteeing the maximum use of the plant given that it has been the subject of sizable investment.

Within the production process, silicon is processed through different machines, following a process flow defined by the R&D department. This flow is based on infrastructure provided by Workstream (a type of MES), which provides operators with elementary information confined to the path that the batch must take. Through Workstream, operators carry out a double process: on the one hand, following automated scripts appearing on computers embedded within the machines, they move the batch between the various machines; on the other, they keep track of the work process. The set-up for each machine, identifying the particular operations to be carried out, is downloaded separately. FTP communication protocols allow the machines to access a server from which Workstream 'picks' the necessary recipe. Each batch is, in fact, associated with specific tooling: Workstream 'reads' the batch (through a barcode reader) and automatically selects the set-ups to be downloaded. The process is highly automatic: for each machine, Workstream (a) identifies and extracts the tooling set-ups associated with the batch; (b) records each operation; and (c) indicates to the operator the next step. Workstream allows the batches to be traced and processed using information contained in the barcode.
In each case, the tooling set-up is prepared by ICT engineers on the instructions of the R&D department.

This has led to the occupational de-skilling of workers: previously, they designed the re-tooling and thus knew the whole process; now, they simply load and unload the batch because many of the steps are being managed directly by the software.

How process planning and scheduling interact with machinery and tools

With regard to the battery companies, Midac wants to introduce between three and five new robots on top of those that already exist; currently, the machines are partially automated but the operator is always needed for loading/unloading. Despite the company stressing that robotisation will not have consequences for employment, union officials and shop stewards highlight that even partial automation produces some effects: it is possible to make increases in production volumes in the presence of constant or even slightly reduced staff numbers (via the non-replacement of retiring staff, etc.). This means that there will not be a wave of redundancies but that, if there is an increase in production volumes, the level of employment will not correspondingly increase: i.e. the increase in productivity is of a labour-saving character.

The battery production processes of Midac and Fiamm are very similar. The first part relates to lead smelting and rolling, processes which are governed by a screen displaying the production parameters. Battery fluid is prepared by a machine that works automatically, using production data entered on a PC. The program has already been installed on the machine: in this way, it is only run by the operator.

In Fiamm, the line is managed by a master panel and the operation of the lines tends to be modular so that, in the event of breakdowns, only single parts need to be reset instead of the entire line. Both in Fiamm and Midac, the communications system between the machines is determined by a 'master' Programmable Logic Controller (PLC) that controls the 'slave' PLCs: for example, the speed is determined by the master potentiometer; a system that, when connected to individual PLCs, monitors whether the machine is working or not. In Fiamm, a SAP-developed ERP tool calculates the production volumes achieved and those that are lost in the event of machine breakdowns and requirements for maintenance. In addition, the worker, at the beginning of each duty, must enter a personal code on the production line and ultimately record its end. Both these aspects are tools to control worker performance.

The final process of assembling the batteries, both in Midac and Fiamm, takes place through different machines; the whole process is highly automated; the role of the operators is that of the loading, control and activation of the line. The constraints on workers, therefore, are determined by the cycle times of the machines. Each machine has a PLC that communicates with the others, while there is a central system that records all the items that have been realised during the shift, allowing the company to exercise real-time monitoring of workers' performance.

In Cebi, the operators find out the work order at the workstation by means of reading a barcode with an optical scanner: the PC automatically shows the volume to be produced, the line to be used and the composition of the work team (each operator's ID must be inserted). The machinery is automatic, being loaded and started by the operator through a PC embedded on the machine using a standard code (the machine is already set according to the general planning defined earlier by ICT tools). Therefore, the operator has only to load/unload the machinery and intervenes only in the case of stops and for process controls. In the latest generation of machines, unloading takes place by a robot, eliminating a work task.

A screen visible to the line supervisor collects data on operating production, making visible the number of wastes by type. Here, a control card is filled in and entered into the PC by an operator, who enters the numbers of good pieces, repairable pieces and those which are rejected (with reasons for the rejection) at the end of each duty. Within the most robotised department, a series of robots weld the flanges, recording and transmitting the production data automatically and in real time.

Finally, the assembly of micro-motors is also carried out using machines that work automatically; a robot provides the pieces for the first manufacturing station and then each subsequent one. In this case also, the operators only have to load/unload, start up the machines and check stops and malfunctions (through the data displayed on the monitors).

At another FM plant, in Crevalcore (Bologna), MES has been implemented: the machining centres are connected to a networked PC (and therefore to a centralised system), so that manufacturing declarations take place through log-in and log-out operations carried out by the worker who records the start and end of each duty via his or her personal ID. A scanner reads the barcode for each operation – at which point, personal ID and work order are associated so that, at any time, the operator may be identified as having been logged on to a particular machining centre – identifying the particular phase of the production and on the particular work order. At the end of the duty, the operator inserts into the ICT system data on the number of pieces processed.

Even if FM's Vicenza plant does not yet have MES, the monitoring of production is still done in real time: the worker records the number of realised pieces on the department PC; in this way, the pieces that have been machined are visible to the ICT system as being available for the next phase. The equipment and production processes are governed by software: all operations are controlled from the point of view of relative costs through ERP; every ten minutes, via another piece of business intelligence software, the operations performed by workers and robots are monitored. The business intelligence software in question is QlikView, which is a reporting tool. It can also be used as an app and is accessible through the company network (by those authorised to access it). The equipment generates data that is collected, stored, processed and classified: in this way, reports are created and control is continuous.

3.5 Impact on workers: production lines and departments

Production planning and scheduling results in work orders being executed on the line or at workstations. Even in the practical execution of these tasks, technology has a very advanced role in determining working conditions and allowing companies to exercise control in real time. However, there are also deskilling effects. The aim of companies is to achieve the highest possible saturation of the workforce and machinery; frequently, the two things coincide because, in order to achieve the maximum saturation of machines, the rhythms of work are thereby intensified. Very often, the times assigned to workers depend on the cycle times of the software embedded in the machines or the instructions sent to them, sometimes remotely, via ICT networks. The cycle times incorporated in the machines and tools are not 'objective', but depend in practice on the social choices of companies to increase work saturation. Sometimes, it is the case that the imperatives of production over-ride the times when a line should be stopped to check that a particular machine is functioning properly and delivering satisfactory product quality. This demonstrates a “formal” tension within different aspects of world class manufacturing that, in reality, confirms the priority order between production numbers and quality, but which is also to the detriment of the saturation of work.

Condition of work and saturation of the work process are dictated by machines and technologies

On the dashboard production lines at MM, the circuit board production process is completely automated: only the production code is entered manually and thus the machine (these are numerical control (NC) machines) is activated by running a program.

Usually, the first operation to be performed every day is to load the program on all the machines; then, for each step, the program is run for each machine: products move between one machine and the next on conveyors according to predetermined timings.

There is a system for collecting data generated by the operation of the machines, installed a few years ago, which allows the entire line to be monitored. On each line, there is a screen controlled by technologists from their workstations which collects production data for each machine and each line. This screen displays all the process information, including any problems and faults.

Each machine then marks out the beginning and end of each processing stage and carries out its operations based on the time established according to the type of product. The installed systems mean that it is possible to trace the entire production process and verify whether the cycle times have been observed.

Subsequently, the circuit boards are transported to the line where the dashboard assembly phase starts. Here also, it is the case that operator intervention consists only of inserting the board and components, while the rest is automated. It is clear that the work of the operators is strongly constrained by the computer programs which are simply run to activate automated processes that have predetermined cycle times.

The working time of workers on these lines, besides being constrained by the cycle times of the programs, is inevitably linked to the quantity of production to be carried out. This quantitative objective is conditioned by the level of operability of the machines; if a machine is not working properly, the cycle should be stopped to request maintenance. However, the imperatives of production frequently prevail over everything else. This consideration confirms that the application of production systems, such as WCM, is exclusively aimed at maximising production via a shortening of cycle times and regardless of the quality aspects that, formally, should represent one of the cornerstones of these models. In fact, the workers we interviewed stressed that, over the years, cycle times and rhythms have continually intensified, in particular via the elimination of all downtime and the intensification of work rhythms.

In MM's power train department, the production cycle is quite similar to that of dashboard assembly. The circuit boards are not loaded manually but by robots. Part of the supply from the warehouse is automated, with two robots pulling a trolley: these move along magnetic strips and are programmed by the warehouseman to stop at the various *kanban* stations. The material is deposited and the worker takes it to carry out operations. All the production lines have *kanbans* for material storage, organised according to production sequences to try to erase as much waste time as possible.

The level of automation is very high; for example, a robot takes care of the positioning of the control units. The task of the operator is to receive the materials to be assembled, then assemble them and put them into a machine that carries out riveting, welding, electrical testing and labelling. Once these operations have been completed, the control unit returns to the worker for visual inspection and subsequent packaging. Here also, the production times are, essentially, the cycle times of the machines; the line screen shows the cycle times of the machines and these must be observed by the workers. It is also clearly the case in this department that the constraints exercised by the machinery (and the programs which run them) are crucial.

The traceability of production is guaranteed by the requirement imposed on the operator to scan the cover label (every 12 pieces) with an optical reader. In this way, when the label is read, the time spent on production is recorded.

Saturation and possible deskilling

In the manufacturing department of STM, the influences which technology is having on working conditions are also characterised by possible deskilling. Prior to the introduction of Workstream, the operator followed and knew all the various phases of the production cycle. Now, manufacturing phases are carried out by machines which are programmed to perform all the operations. These machines have been designed to incorporate FTP communications protocols that manage the entire download of the tooling set-ups from the server which provide the machine with its operating instructions.

On some lines, the level of automation is currently such that it is possible to operate them remotely, i.e. to launch the setting-up process directly from offices. Therefore: a) the steps that a lithographic machine must take are programmed; b) there is a double programming: of the flow, that is the sequence of machines; as well as of the processes that each single machine must carry out; and c) the programming encompasses the ability to activate each machine either from within the department (that is, on each machine) or remotely. The machines are very complex; so much so that the supplier companies have groups of workers who work permanently with STM employees at the Milan plant as only they know all the details of operation and programming.

This has strong consequences for the human-machine relationship: the machinery, in fact, operates on the basis of programs written by people who are not the operators who use them, working on the basis of logic that has no room for the understanding, and therefore the control, of STM's workers.

Intervention in industrial processes to achieve tightly-controlled flows of production

In both Midac and Fiamm there are processes whose times are dictated by chemical and physical constraints (paste preparation, casting, drying, etc.). However, the companies have been intervening in all these phases to shorten the times: in Fiamm, to shorten curing times (from 15 days to 24 hours), a special oven has been installed; while, to avoid loss of time due to production changes, new machinery (auxiliary ovens) etc. have been installed. Above all, Fiamm has compressed machine times on its ironing line: the production volumes of the line have been increased from 22 metres per second to 32 by dint of speeding up machine movements with the use of inverter motors. In this way, all the machines on the line have been speeded up to make the line speed uniform: by changing the general setting of the system (on the master panel) the speed of individual machinery may be changed.

In Midac, the installation of PLCs on all equipment allows real-time signals to be sent to the maintenance department (via monitors and smartphones) to guarantee immediate intervention in the event of faults, minimise machine downtime, obtain the necessary spare parts and realise scheduled maintenance.

Meanwhile in Fiamm, in order to guarantee that the machinery is fully operational, significant pressure is exerted on maintenance technicians: they receive calls on a mobile phone and must enter every alert on Geocall. This is an ICT system that includes many functions: receiving reports directly from equipment; creating work packages to be performed with scheduled machine downtime; assigning interventions to technicians or teams based on production shifts; reporting works and opening new requests for intervention through an operational workflow; defining the check list of controls; and checking activities in real time. It is a highly automated system which allows the company to exercise a very strong form of control of the times and performance of maintenance technicians whose job is to restore operation as quickly as possible. The maintenance technician has to insert a personal ID on the PC embedded on the machine to track the start and end of activities; for each intervention, a report must be compiled that is checked by the head of department and which evaluates the time spent and the quantity/quality of the performance.

Re-tooling machinery to reduce downtime

In Cebi, the automated lines produce 500-550 pieces an hour; to feed these lines continuously, the flanges are welded by robots.

Thanks to the robotized welding of the flanges, these parts are supplied to the assembly line at intervals (cadencies) dictated by the operating programs of the robots, forcing the workers to adapt.

In addition, also on the assembly line there is a constraint in operation dictated by technology. The machine, once loaded, runs autonomously and its operation time is used by workers for control, restore and registration activities; primarily, however, the constraint on workers reflects the need to unload the machine because, in the absence of this stage, the equipment would stop. In the event of a product changeover, line retooling times have been drastically reduced from 45 minutes to 15 using a PC that recalls the set-up corresponding to the new production batch. Re-tooling and maintenance have been put in the hands of the operators, increasing their workloads, and the company no longer hires maintenance technicians. Two particular elements of Lean Production are in play here: SMED (Single-Minute Exchange of Dies), which seeks to reduce plant setting times and eliminate waste; and Total Preventive Maintenance whose aim is the optimisation of capacity utilisation of the lines through the progressive reduction of unplanned extraordinary interventions.

It is also the case in Cebi, therefore, that technological and organisational innovations have led to the possibility of achieving higher production volumes with the same number of staff, whose jobs have become characterised by great flexibility and variability.

One of the main investments in connection with Industry 4.0 at Cebi concerns the wiring-up of some machines in order to have data accessible in real time via PCs or other devices, reducing time and steps. Each machine will, as a result of this greater connectivity, be able to communicate and send alerts to the person in charge of the production process so that he or she can intervene immediately, avoiding machine downtime. This will contribute to the improvement of OEE, in terms of the degree of utilisation of equipment. Some lines will be equipped with a central PC that collects data from PLCs and other devices, data which will then be passed to the MES. Other lines will have a direct PLC-network connection, with direct data transmission to the MES. In this way, the assessment of the OEE parameter is used to put the group's plants, and therefore the workers, in competition with each other.

Effects on white collar staff

In STM's design offices, design automation has been implemented through the use of increasingly complex design and simulation software. In particular, digital design offers much more advanced support for CAD (Computer Aided Design) than analogue design. The change in the design sector has been significant and extends to the deskilling of the designers. The design process is very complex and involves several steps; inevitably, the objective of the company is to shorten the times for these steps, and their number, as far as possible. For this reason, STM has defined a 'process design kit': a set of software tools that allows the automation of as much of the design as is conceivable. The definition of precise rules corresponds to the objective of minimising change to reduce costs. To achieve this goal, STM addressed its requirements to companies specialised in the supply of CAD, such as Cadence, Mentor and Synopsys which provide about ninety per cent of the tools used in design. Their software is able to count how many times a function is pressed, how many clicks are made, etc. and thus its ability to control the performance of the designers is, therefore, extremely pervasive.

STM also wants to document all the steps taken in design – which, in addition to being an extra tool for control, entails additional workload. Greater workloads and complex processes result in a highly stressful situation for workers. Moreover, STM can exert control thanks to the traceability of all its processes: when problems occur, the company is able to identify which operators have been responsible and this is adding to the stressful climate.

Meanwhile, the designers feel less specialist and skilled than before because the software has 'absorbed' many of their skills.

3.6 A possible trade union bargaining agenda

The findings of this research (and other similar ones carried out in collaboration with employees organisations of Cgil, Fiom in particular), have made it possible to begin to define an agenda of bargaining issues.

First of all, the theme of information rights. The organisational and technological innovations that are applied in the plants derive from precise choices made by the management and ownership of the companies that must be communicated, in good time, to the workers and their representative organisations. The National Collective Agreement for Metalworkers provides that the management of companies with at least 50 employees must provide the trade union representatives with a series of information concerning, among others, a) the strategic choices of the companies on the production activity, b) the changes in the production system that affect the technologies adopted, the overall organization of work and the type of production; c) the outsourcing of phases of the production activity. Unfortunately, the information system that companies implement with regard to workers' organizations often works very partially and late. The research has shown that the extent of the technological and organizational transformations that companies are implementing has such an impact on workers that it is necessary to fully implement the information rights provided by the National Collective Agreement, so as to have, in good time, useful information to negotiate with the company the actions it intends to implement.

The research revealed the need for the union to regain the opportunity to discuss work organisation. This means the possibility to discuss, in the first instance, cycle times, saturation and workloads with companies. With full-time union officials and shop stewards, objectives were discussed in relation to these issues which have become part of the union's bargaining agenda, despite the fact that Italian companies refuse to recognise the right of the union to negotiate work organisation issues on which they claim to be able to take decisions unilaterally. Secondly, the possibility of discussing work organisation also involves bargaining on broader aspects, such as production volumes and workforce size.

Negotiation of cycle times, saturation and workloads, for example, can lead to a lower workload for each worker, thus determining the need to expand the workforce to maintain overall production volumes. This need is particularly strong in those departments where the pressure on workers is very hard.

The organisational and technological innovations implemented by companies, aimed at maximizing productivity through a greater degree of work exploitation, are also causing problems in terms of health and safety. These problems affect both classic musculoskeletal disorders and forms of work-related stress. The Italian law obliges companies to adopt all measures to protect workers, including the respect of ergonomic principles in the design of workplaces, in the choice of production equipment and in the definition of work and production methods. The implementation of these safety measures must take place with the involvement of the trade union: in many situations, the discussion with companies on health and safety problems allows for the involvement of work organisation issues which, as said before, companies would like to determine unilaterally.

Levels of stress and pressure on workers have also worsened as a result of the use of technological systems to control work performance: trade union bargaining is trying to limit and regulate the use of these tools. This issue is not only limited to privacy but is functional to a certain model of work organisation.

Last but not least, the issues of outsourcing and production chains. In order to limit the negative consequences of these corporate strategies, CGIL has defined the objective of practising so-called «inclusive bargaining»: i.e. bargaining that also involves the workers of sub-contractor companies and supplier companies. This is a very ambitious and difficult objective, but it can no longer be postponed in the light of the concrete form taken by the industrial structure in Italy (and in Europe).

4. Conclusions

The structure of the European automotive industry is characterised by two main aspects: the production chain is highly fragmented and dispersed across different countries; but, at the same time, supplies must be sent to OEMs on a just-in-time basis, so all the stages of the entire production chain must be closely synchronised. Industry 4.0 technologies make it possible to coordinate these increasingly complex and fragmented chains, as a result of the use of ICT tools and apps that make it possible to manage and monitor all the phases of the process in real time.

Italian automotive supply chains are under pressure from two entwined phenomena: the reduction of vehicle production in Italy, which has obliged Italian suppliers to increase the volumes of components supplied to foreign car manufacturers; and the competition exercised in this area by low-cost plants in central and eastern Europe that are supplying the western European automotive industry.

Italian supplier companies are responding to this pressure by intensifying the exploitation of the workforce.

Technological (Industry 4.0) and organisational (Lean Production) innovations are closely connected and, as a result of these connections, are leading to new models of work organisation. These new models are having a serious impact on working conditions, symbolised by the intensification of the pace and rhythms of work; the saturation of workloads; the real-time control of work performance (in turn leading to workers being subjected to increased work-related stress); and often also to occupational deskilling.

A different use of technologies, i.e. to support workers rather than to establish the ground for their further exploitation, is certainly possible: but this requires trade union intervention for a different organisation of work and production. It is clear that technologies cannot be negotiated only from the point of view of their use in practice, but starting from their conception and design: only in this way will it be possible to plan interventions which are in favour of workers (Dina 1982; Noble 1979; Panzieri 1961).

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Appendix

Overview of case studies

Name	Italian employees	Multinational
Cebi Motors (Tier 2 supplier)	226	This company is part of Cebi Group: this is a Group headquartered in Luxemburg, with more than 3,000 worldwide employees and 11 plants in eight different Countries
Fiamm Energy Technology (Tier 1 supplier)	394	Fiamm was bought by Hitachi, so it became an Italian subsidiary of this multinational company
Midac (Tier 1 supplier)	485	Italian company with worldwide presence (this company had subsidiaries in France, Germany, UK, Sweden, Nederland, Australia)
Fonderie di Montorso (Tier 3 supplier)	413	Italian company
Magneti Marelli (Tier 1 supplier)	5101	Magneti Marelli has been sold by Fiat (FCA) to the Japanese group Calsonic Kansei: both groups (i.e. both Magneti Marelli and Calsonic Kansei) have a worldwide presence of production plants. Together they have created a company (Marelli) that has over 170 sites worldwide (production plants and research and development centers).
STMicroelectronics (Tier 1 supplier)	10300	This Group has a worldwide presence and a total of 46,000 employees. The company involved in the research is the Italian subsidiary.

Chapter 8
The transformation of jobs and working conditions: Towards a policy response

Monika Martišková

1. Introduction

The introduction of new technologies and their impact on workers is not a new topic among scholars; innovation is perceived as an embedded feature of capitalism and necessary for capital renewal (Hall 2010). However, there are some aspects which make the current changes different from previous waves of technological revolutions: the speed of innovation and its destructive potential regarding technologies currently in use but which are quickly becoming obsolete (Komlos 2016); their association with jobless growth (Brynjolfsson and McAfee 2012); and their facilitation of new business models that reach across the globe with minimum physical capital and with a very low number of employed workers, which is especially relevant in the IT sector (Soete 2018). In production areas, new technologies are used to reduce costs by limiting the input of labour while preserving or even increasing production levels. The transformation of working conditions and the reduction in job opportunities are consequences of the deployment of new technologies in the production process which deserve researchers' attention.

In particular, there is an urgent need to understand the ongoing changes caused by new technologies in order to provide relevant policy responses to prevent a deterioration in working conditions for workers in production. One of the biggest challenges facing the implementation of Industry 4.0 is the adaptation of workers' skills to new technologies. Business leaders in the three countries that we have studied in the central and east European (CEE) region considered the lack of skilled workers to be the biggest obstacle to the implementation of Industry 4.0. However, the policy responses at company, regional and national level are uncoordinated and unsystematic. Effective reskilling and retraining policies are costly and require both personal engagement and a plausible institutional framework whose parameters are set by collective bargaining and/or by public institutions. We argue that, in the context of CEE countries, effective policy responses to protect workers from negative impacts or to provide reskilling are missing. In this chapter, we discuss the reasons for these attitudes but also the potential consequences of inaction.

We have studied the automotive industry as a model sector for the introduction of new technologies and the impact these are having on working conditions in three CEE countries – Czechia, Hungary and Poland. The aim is to depict the transformation of working conditions related to the introduction of new technologies based on in-depth interviews with managers, trade unionists and workers at specific automotive industry sites and to analyse their policy responses. Interviews with actors representing sectoral organisations of trade unions and employers were also conducted. Our interviews focused on various aspects of changes related to the deployment of new technologies in production including: the installation of robots; the use of new electronic devices; the implementation of systems that allow production synchronisation, such as Manufacturing Execution Systems (MES) or Enterprise Resource Planning (ERP); the automation of internal logistics; and some advanced technologies such as 3D printing or virtual reality at shop floor level. We were interested in the impact of these technologies on work schedules, changes in workloads, the impact on workers' autonomy when performing particular tasks and changes in the character of the tasks themselves (whether they are more routine or more non-routine), as well as the changing requirements for workers' levels of education.

Our qualitative approach has allowed us to understand the perceptions of local employees and stakeholders on the deployment of new technologies and their impact in transforming jobs. Particular emphasis was given in the research to the working conditions of shop floor workers who are expected to experience the most dramatic changes in both job content and job opportunities and in their prospects for retraining.

Despite trade unions being expected to play an important role in the promotion of retraining policies at company level (Jolly 2018), our research results suggest that this is not a collective bargaining priority in the majority of companies we studied. The reason is that, despite the implementation of labour-saving technologies, a displacement of labour has not occurred since, in recent years, the region has suffered significantly from labour shortages which have further postponed policy responses. We conclude that limited recognition of the negative impacts of new technologies on working conditions and employability has prevented the establishment of mitigation strategies at company, regional, sectoral and national level.

In this chapter we first discuss job transformation in the CEE region and the observed impacts on the quality and quantity of jobs, and then we present our methodology. In the third section we investigate the impact of new technologies in terms of the numbers of jobs in CEE automotive plants and then discuss aspects of the transformation in job quality. We then comment on the policy responses of trade unions in the three CEE countries, with special emphasis on reskilling policies. In the last section we summarise our findings.

2. Impact of new technologies on working conditions and job opportunities

Workers in the automotive industry are expected to be confronted with change in two different, but not mutually exclusive, ways. One relates to the restructuring of supplier chains and the varying location strategies of multinational corporations (Pereira and Romero 2017; Kagermann 2014) which Andrea Szalavetz in chapter 3 discusses in detail in this book. The second relates to the introduction of new technologies in the workplace which might have an impact on job opportunities and also modify job content (Bonekamp and Sure 2015). In this chapter, we devote attention to the second aspect of job transformation at plant level, focusing on the impact on those workers directly involved in production processes.

Employment levels are expected to shrink mostly among manual workers whose opportunities to participate in additional training may be more limited, while educated non-manual workers will have higher probabilities of adaptation to job transformation (Arnold *et al.* 2018). Especially for lesser educated workers, the job reduction effect of technologies is highlighted in a study by Acemoglu and Restrepo (2017) who estimate that each additional robot reduced between three and six jobs between the 1990s and 2007 in the US. For six EU countries (Finland, France, Germany, Italy, Spain and Sweden), the recently estimated job reduction effect was, over a similar period, also negative; with each additional robot introduced leading to two job losses (Chiacchio *et al.* 2018). The job reduction effect is, however, not distributed evenly because young people, lesser educated workers and those working in industry are most exposed while, for instance, technician employment levels have actually increased with the higher deployment of new technologies in the most recent decades (*ibid.*).

Scholars have distinguished between the displacement and the productivity effects of new technologies (Dauth *et al.* 2017). While the displacement effect refers to the reduction of jobs because of the introduction of new technologies, the productivity effect refers to increases in the level of productivity leading to increases in employment. A recent study from Germany suggests that the displacement effect of technologies may be counterbalanced by a productivity effect in other sectors, leading to increases in employment levels elsewhere and making an economy seemingly unaffected by the introduction of technologies (Dauth *et al.* 2017). However, even where there is no overall effect on employment levels, one may question the quality of jobs created under the productivity effect as these are, mostly, created in services and are both less secure and more precarious (Novta and Pugacheva 2018). Moreover, Erturk (2019) suggests that previous experience might well not be repeated during the fourth industrial revolution. For instance, the demand for technicians and other high-skilled workers may decrease in forthcoming years on account of individual productivity growth thanks to the possibilities provided by advanced technologies; therefore, new technologies might have a net negative effect on employment levels overall, as well as among manual workers in particular.

Besides the reduction of job opportunities, workers are expected to face a deskilling effect as regards their own jobs. A deskilling effect occurs when technologies deconstruct complex tasks into simple steps which make work much easier but which also decrease the requirement for workers' skills (Attewell 1987). Evidence suggests that it is mainly workers involved directly in production who have experienced a deskilling effect in the last fifty years (Kunst 2019). Another aspect of deskilling, as recognised in the labour sociology literature, is workers' decreasing autonomy in decision-making (Agnew *et al.* 1997; Erturk 2019), which Industry 4.0 technologies are expected only to intensify (Butollo *et al.* 2019). Crouch (2018) also recognised the threat of increased control within the labour process through the implementation of sensors, chips or wearables – various devices attached to one's clothing or body, serving to monitor movements and improve performance – which contribute to losses in workers' autonomy and an increase in the level of control to which they are subject. New technologies implementation also contributes to increased levels of stress of employees (Körner *et al.* 2019).

In contrast to the deskilling effect of new technologies, increasing task complexity is perceived to mean the upgrading of workers because only the more difficult and complex tasks will be performed by humans while new technologies will handle repetitive or physically difficult tasks (Kergroach 2017). Several authors suggest that increasing task complexity and the related requirements for better educated workers are an inevitable part of the technological revolution (Bonekamp and Sure 2015; Porter and Heppelmann 2014). This is the reason why high expectations are assigned to Industry 4.0 technologies when it comes to the prospect for workers' upskilling, as workers are expected to be accomplishing more complicated and advanced tasks in the future (Hirsch-Kreinsen 2016). On the other hand, workers' upskilling requires comprehensive retraining policies which are not always provided in the workplace or by public institutions.

Retraining being provided to workers in the workplace is considered to form one aspect of decent work because, through retraining, an employee is given further chances to be employable in the future (ILO 2019). Although employers' motivation to provide retraining is limited, according to Cappelli (2004) most employers whose business relies on social capital are willing to provide more retraining. Similarly, Benhamou (2018) distinguishes the learning and the lean organisation, pointing out that lean organisations provide less training to workers than learning organisations. Retraining policies are further dependent on the size of company, capital intensity and unionisation rate. In the case of the automotive sector, an important factor is also the position of the company in the production chain, with lower tier suppliers having fewer resources to devote to employee training and reskilling than ultimate manufacturers (OEMs). Trade unions, through partnerships with employers, may employ effective policies which help workers reskill. A good example is provided by the employment security councils operated in Sweden by employers and trade unions and which provide redundant workers with assistance in reskilling and employment (Engblom 2019). In the changing labour market, retraining seems to be a crucial aspect of labour market policy in which trade unions should play an important role (Jolly 2018; Bamber 1989).

We will conceptualise our empirical evidence based on the effects that introductions of technology may have for working conditions and jobs. Our empirical investigation concentrated on the displacement effect and the deskilling effect of new technologies, looking also at current policies dealing with the retraining and reskilling of workers as an important element of mitigation strategies. In the next sub-section, we briefly describe the context of the CEE region and then, in the subsequent section, introduce the sample of companies we interviewed and our empirical findings.

2.1 Job transformation in central and east European countries

Looking at the prospects for CEE countries, job transformation is expected to hit the region significantly with new technologies having a prevailing displacement effect. The main reason is the high share of manufacturing jobs in these countries. In the last twenty years, the CEE region has experienced a growth in manufacturing jobs, especially through job relocations from west European countries to central and east European ones in the automotive and related industries (Pavlínek 2019). A large part of these manufacturing jobs are based on routine tasks that are expected to be easily automated in the near future (Keister and Lewandowski 2017). Despite the CEE region not being a frontrunner in the introduction of new technologies (Krzywdzinski 2019), there are various predictions that many manual and routine jobs are expected to disappear, or change substantially: one OECD study predicts for Czechia that around 15 per cent of jobs are at a high risk of automation while another thirty per cent are at a significant risk (Nedelkoska and Quintini 2018); while the prediction of Chmelař *et al.* (2015) is that ten per cent of jobs will be lost and another 35 per cent transformed.

The reason for such a high threat of job losses in CEE countries is their high share of manual workers. While plant and machine operators, according to the ISCO classification, take up 14 per cent of the total workforce and 36 per cent of manufacturing in Czechia, in Germany their overall share in employment is 6.3 per cent and, in manufacturing, 13 per cent. The figures for Hungary and Poland are even higher than for Czechia (see Table 1). This is a consequence of the intensive relocation of jobs by west European companies to CEE countries in the last twenty years. About 387,000 jobs have been destroyed in the automotive industry in western countries while almost the same number have been created in CEE countries: about 329,000 between 2005 and 2016 (Pavlínek 2019). The main drivers have been low labour costs and state subsidies, which have created largely medium-skilled and routine-intensive jobs in the region (Keister and Lewandowski 2017).

Table 1 **Share of plant and machine operators in manufacturing**

	Plant and machine operators TOTAL	Plant and machine operators in manufacturing	Total employment	Total manufac-turing	% plant and machine operators in total employment	% plant and machine operators in manufacturing in total manufacturing employment	% manufacturing in total employment
HU	666.4	378.4	4,373.4	984.4	15.2%	38.4%	22.5%
PL	1,685	737.8	16,078.8	3,380.4	10.5%	21.8%	21.0%
CZ	727	395.9	5,093.9	1,438	14.3%	27.5%	28.2%
SK	370	223.8	2,502.1	620.6	14.8%	36.1%	24.8%
DE	2,560	1,016.3	40,481.6	7,804.3	6.3%	13.0%	19.3%

Source: Eurostat [lfsa_egised, lfsa_eisn2], own calculation

The level of labour costs in CEE countries may be hampering the introduction of labour-saving technologies since the rate of return on investment is negatively correlated with the level of labour costs. However, other factors such as attitudes and the general level of investment and competition in the sector and in the country play an important role. When looking at Czechia, Hungary and Poland, and comparing them with Germany (their most usual business counterpart and/or the owner of many sites), the relationship between the level of labour costs and the introduction of industrial robots confirms the negative correlation between labour costs and the number of implemented robots. While labour costs in automotive in all four Visegrad countries oscillates between

10,92 EUR per hour in Poland to 15.12 EUR per hour in Czechia, in Germany hourly labour cost is 48 EUR per hour.[1]

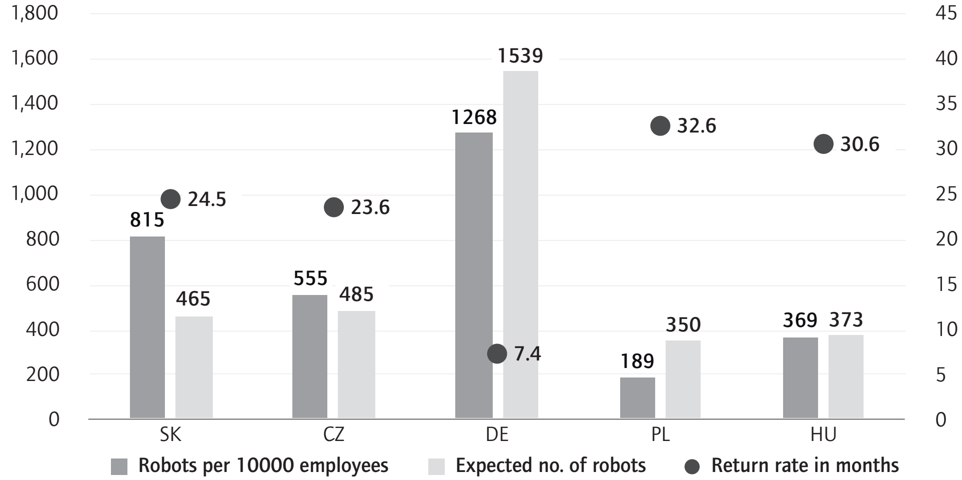
We have compared robot adoption rates with actual labour costs to see how the introduction of robots corresponds to the level of wages in a given country. We followed Atkinson's (2018) methodology, assuming that a new industrial robot costs $250,000 and would replace two workers in two shifts working fifty weeks per year, on the basis of average labour costs compiled by Eurostat. Computed return rate (see Figure 1) for automotive is 23.6 months for Czechia, 30.6 months for Hungary and 32.6 months for Poland while for Germany the replacement rate is 7.4 months. From these rates of return, we can derive an expected figure for the number of robots introduced into production per ten thousand employees and compare the actual rate of introduction of industrial robots with the worldwide average. Interestingly, we arrive at the conclusion that Czechia and Slovakia have a higher than expected number of robots introduced in production given their labour costs, while Poland and Germany are below the expected figure. Hungary's rate of industrial robots in production corresponds to its level of labour costs.

The higher than expected introduction of robots in Czechia and Slovakia indicates that we need to take into account other factors than simply-assumed labour costs in the given country. Despite not being considered in Atkinson's methodology, decision-making on the introduction of robots is influenced also by labour costs in the home countries of multinationals. The wage difference between western and eastern Europe still provides incentives for multinationals to remain in eastern Europe. At the same time, rising labour costs in eastern countries has, in recent years, motivated companies to invest in labour-saving technologies there.

Significant role in investment strategies is also played by the level of competitiveness, not only in the sector but also between different sites within the same company. Some level of discretion over individual investment decisions is retained in particular plants, which sites use to enhance their competitiveness. Another factor in how investment decisions are made is customers' control of production in suppliers within the chain, including specifying what equipment should be used to produce particular parts, which often also entails new investment in more advanced technologies. All these factors are relevant in the case of our three studied countries (see also chapter 3 by Andrea Szalavetz).

1. Eurostat, labour costs data for 2018 for NACE C manufacturing, increased by 20% for automotive [lc_lci_lev].

Figure 1 **Actual and expected number of robots implemented in automotive on average labour costs in five countries**



Source: own compilation, based on Atkinson (2018) (data on labour costs: Eurostat lc_lci_lev; robots: IFR 2019)

3. Transformation of jobs in Czechia, Hungary and Poland

While the level of advance in the introduction of technologies can be characterised as heterogenous in the companies we visited (see chapter 3), at least some effort towards using, or trialling, new technologies were reported in all of them. The companies in our sample face multiple pressures in the sector which has resulted in the deployment of new technologies. First, there are constant cost competition pressures between the subsidiaries of multinationals. Second, a tight labour market in each of the three countries has proved to be a serious obstacle to satisfying increased demand in recent years. Third, there are rising expectations among customers of the increased variability of products which can be attained through innovation in production technologies and processes. As a result, they are being constantly forced to increase the effectiveness of their production capacities through the introduction of new technologies as a means of increasing the efficiency of production and decreasing production costs.

Our respondents were most familiar with the introduction of robots on production lines and/or of automated systems in internal logistics. In some cases, they also mentioned elements of cyber-physical systems, such as production digitalisation and data analysis. Installation of advanced technologies which improve workers' performance, such as 3D vision, wearables or data glasses, were mentioned mostly in OEMs.

In our empirical research, we concentrated on evidence for the transformation of jobs associated with new technologies. The implementation of labour-saving technologies embodied in industrial robots mostly affects shop floor workers as regards the quality of their work as well as job opportunities in general. When investigating the impact of new technologies on the working conditions of manual workers, we stick to four aspects widely discussed in the literature and in public debate: (1) the deskilling effect, demonstrated by decreases in job difficulty, increases in job cadence and a decreasing level of autonomy and control; (2) improving health and safety at work; (3) changes in job opportunities; and (4) the retraining prospects of workers in our sample companies.

Our research was guided by a series of questions related to the impact of new technologies on working conditions:

a. Changes in the number of jobs: To what extent have new technologies reduced jobs?
b. Deskilling: To what extent are workers experiencing the simplification of work tasks and the loss of autonomy in work performance?
   — Changes in physical job difficulty and task complexity: Do we observe at plant level a decrease in physically difficult jobs? Are the new tasks being assigned to workers more or less complex?
   — Changes in job cadence: To what extent are new technologies increasing the speed of work?
   — Level of control: Are employees exposed to increased levels of control by employers?
c. Access to training: Bearing in mind knowledge of the importance of retraining in an era of the introduction of disruptive technologies, are retraining policies at company level being promoted by trade unions or employers?

Our sample consists of 28 companies, of which nine are OEMs, 17 are tier one producers and two are tier two producers (see Table 2).[2] Our sample contains 34 respondents from 28 operations in Czechia, Hungary and Poland, of which 17 are trade union representatives at company level (or are works councillors) while 17 are various management representatives from different fields (four Industry 4.0 managers; four production managers; three IT managers; two CEOs; two HR managers; one logistics manager; and one representative of an education facility). Additionally, in Czechia and Hungary, five representatives of trade unions and employers at sectoral level were also interviewed. Semi-structured interviews, based on a pre-defined questionnaire, lasted between sixty and ninety minutes and were recorded following the consent of the respondent. Interviews were conducted in the course of 2018 in Hungary and Poland and in 2018 and 2019 in Czechia. Building on the 39 interviews we conducted in the three Visegrád countries, we have also conducted three focus groups with 13 employees working at shop floor level in internal logistics and on assembly lines in two Czech tier one suppliers.

2. Data collection and analysis was conducted by Monika Martišková in Czechia, Kristóf Gyódi and Katarzyna Śledziewska in Poland, and Andrea Szalavetz in Hungary.

Table 2 **Respondents in our research from company level**

Type of respondent and country	OEM	TIER1	TIER2	Total
CZ	**5**	**9**	**2**	**16**
Education facility employees	1			1
Industry 4.0 manager	1	1		2
IT manager		1		1
Logistics manager		1		1
TU representative	3	6	2	11
HU	**3**	**8**		**11**
CEO		1		1
HR manager		2		2
Industry 4.0 manager		2		2
IT manager		2		2
Production manager	1			1
TU representative	2	1		3
PL	**4**	**3**		**7**
CEO		1		1
Production manager	2	1		3
TU representative	2	1		3
Total	**12**	**20**	**2**	**34**

Source: own data

During the period of our research, between 2018 and 2019, the majority of the companies which we visited were expanding their production capacities while simultaneously introducing labour-saving technologies. The trend of absolute decreases in the number of workers was observed in only some of the companies in our sample: out of the 28 companies, only three experienced a decrease in employment between 2013 and 2018 while in 19 employment increased by more than five per cent (see Table 3). Many of these increases at company level are attributed to the inflow of foreign workers into the countries. In Czechia, the number of foreign workers reached 580,000 while, in manufacturing positions (ISCO 8 – Plant and machine operators and assemblers), their number tripled between 2014 and 2018 from 42,000 to 124,000 (see Figure 2). In Hungary, the number of foreign workers grew from 140,000 to 180,000 between 2013 and 2018;[3] while, in Poland 400,000 foreign workers were registered in 2018.[4] As a result, we could not observe that new technologies had resulted in a displacement effect in the period under study because, despite such introductions, the expansion of production had led to increases in employment levels in most of the companies.

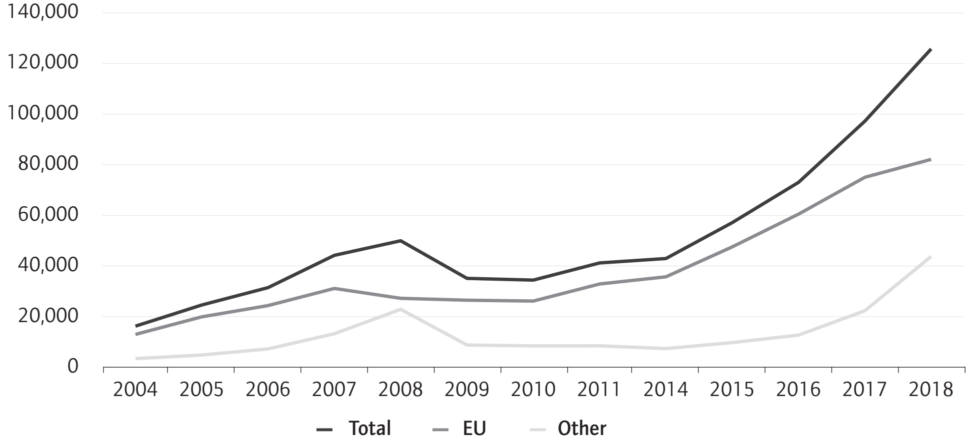
3. https://www.ksh.hu/docs/eng/xstadat/xstadat_annual/i_wnvn001b.html.
4. https://udsc.gov.pl/400-tys-cudzoziemcow-z-waznymi-zezwoleniami-na-pobyt/

Table 3 **Revenues and employment changes in the sample companies**

Global production network position	Country	Employees in 2018	Average change between 2013 and 2018
OEM	CZ	3,287	0.0%
OEM	CZ	2,248	0.3%
OEM	CZ	22,932	4.8%*
OEM	PL	1,876	-5.5%**
OEM	PL	8,020	2.9%**
OEM	PL	3,245	8.8%**
OEM	HU	3,550	6.9%
OEM	HU	1,251	10.7%
OEM	HU	11,803	4.3%
TIER1	CZ	3,764	10.4%
TIER1	CZ	1,396	15.8%
TIER1	CZ	1,141	9.1%
TIER1	CZ	9,000	6.8%*
TIER1	CZ	726	6.2%*
TIER1	CZ	1,872	2.6%
TIER1	CZ	1,908	9.2%
TIER1	PL	8,499	15.9%
TIER1	PL	7,183	10.0%**
TIER1	PL	1,219	15.0%
TIER1	HU	3,731	5.7%
TIER1	HU	4,827	7.2%
TIER1	HU	266	-10.1%
TIER1	HU	1,343	16.3%
TIER1	HU	2,394	14.9%
TIER1	HU	1,033	5.1%
TIER1	HU	718	7.3%
TIER2	CZ	203	-2.4%
TIER2	CZ	848	7.9%

* Averages between 2013 and 2017
** Change only between 2017 and 2018
Source: own compilation based on data from companies' final accounts for Czechia, Hungary and Poland

Figure 2 **Employment of foreign workers in Czechia**



Source: Czech statistical office, https://www.czso.cz/csu/czso/foreigners-in-the-czech-republic-uvmo2pjmg2

3.1 Deskilling effect of new technologies

In this sub-section, we aim to assess the deskilling effect of the introduction of new technologies in the companies in our sample. Here, we will focus on changes in physical difficulty and task complexity, in job cadence and in the level of control to which employees are subject.

Respondents confirmed in our interviews that work automation had a positive impact on the physical difficulty of manual labour. In painting and welding shops in particular, significant improvements were reached through the introduction of new technologies. On production lines, the partial automation of the most demanding and difficult tasks occurred, e.g. in lifting heavy parts or improving ergonomics. A decrease in the manual difficulty of work was also recorded in internal logistics through the introduction of automated guided vehicles (AGVs). Improved health and safety in workplaces marked previously by physically demanding work was one of the impacts of job automation which was most appreciated by our respondents.

Decreasing the physical demands of work was, however, outweighed in many workplaces by increases in work cadence and the implementation of advanced lean production principles. Respondents who were able to compare longer periods highlighted, in particular, the increased work cadence on lines, e.g. in welding or assembly. When examining the specific contribution of new technologies to increased workloads, respondents revealed, however, that the recent introduction of new technologies is not the only reason for workload increases and that this process is rather continuous, being associated with lean production principles.

Despite the theory that new technologies are expected to leave humans mostly more complex tasks to deal with, with repetitive and physically difficult tasks being picked up instead by machines, our evidence on job transformation suggests that the greater deployment of technologies in the production process does not necessary lead to increased work complexity and workers' upgrading but, rather, to workers being asked to multi-task. In other words, workers being relieved from hard and repetitive work which is now being performed by a machine does not mean that the worker experiences upgrading; instead, he or she is now being made responsible for feeding and controlling the positions and performance of several machines at once. For instance, in Polish companies, respondents confirmed that the introduction of robots implied for each employee the responsibility for a longer fragment of production and an increased variability of the tasks that one worker should know; with, at the same time, increased exposure to time pressures with upgrading not being the result.

An emerging issue from our interviews was the implementation of advanced control and traceability techniques in production, with critical attitudes to increased work pace and control also appearing in our interviews: 'I must acknowledge, operators' work has become more stressful than it used to be. With smart sensors measuring every movement, it is easy to trace which operator committed a mistake. Or else, some workers used to work faster than the average and spared some time to have a rest. Now, this is impossible: every processing step has a predetermined processing time; you should neither work faster nor slower.' (Hungarian respondent)

As an illustrative example, we can examine the machine-feeding jobs which are spreading in production areas in the companies we visited. These robots standardise working tasks to such an extent that workers have become a mere appendix to the machine, because the worker's task is only to put the right components in the right place, with the rest being done by the robot. This also contributes to a significant loss of workers' autonomy when performing the task, as one of our respondents suggested: 'Operators simply monitor the equipment. If a green light is blinking, they needn't do anything; if, however, the light turns to red, they must follow a predetermined, simple protocol. Otherwise, they have little autonomy to intervene: they can stop the machinery or call the line supervisor or maintenance staff. Previously [in the early 2000s], they were allowed to repair the fault if they had adequate skills or creative ideas; now, with modern production machinery, it is strictly forbidden' (Hungarian respondent). Loss of autonomy was also highlighted by the Czech workers in our focus group. When a problem in production occurs, workers are obliged to call technical support, which may take some time and which decreases production pace and, potentially also, the wages of those workers. 'They do not allow us to touch the screen despite it seeming trivial what the technician does there. I would appreciate to learn how to handle at least the basics in these new robots, but we are not required to know it' (focus group participant in Czechia, 2019).

Our interview evidence suggests that workers are being exposed to new technologies having deskilling effects, mostly in terms of work simplification and the loss of autonomy within production while, at the same time, experiencing rising work takt (the time for the production of one unit of output, measured from the start of one unit and concluding at the start of the next) as well as requests for multi-tasking. Industry 4.0 technologies further advance the principles of lean production in the companies adopting them, so our respondents did not perceive the changes as radical but rather as evolutionary. This contributes to their lack of a critical attitude towards the deployment of new technologies in production.

We will return to a discussion of the attitudes of trade unions to new technologies and their policy responses in a later section.

3.2 Changes in skills requirements and jobs in the automotive sector

Changing working conditions will have consequences for the composition of the workforce in terms of educational level and the complexity of work tasks. In this sub-section, we aim to assess the impact of new technologies on job requirements and opportunities in the automotive industry for shop floor workers. For that purpose, we consider traditional occupations in workplaces based on the European Automotive Skills Council (EASC) report and our own evidence in respect of: maintenance technicians; CNC operator/tool and die makers; paint technician/motor vehicle painters; assembly line operative/ assemblers; materials planning analysts; welders; and logistics assistants. In the accompanying Table 4, we have provided an overview of current educational requirements according to ISCED levels, summarising how new technologies transform job content and how they contribute to developments in the number of jobs. In the final column, we indicated changes in skill requirements regarding each position based on our interviews.

Logistics assistants are considered the lowest-skilled among production workers. They are exposed to decreasing job opportunities wherever internal logistics is being automated. This, however, varied in the companies we visited occasionally because of premises being unsuitable for automation (e.g. in one company respondents indicated that outdated production premises, with steps on the floor, had prevented the introduction of AGVs). However, where the automation of internal logistics is implemented, there is a decreasing demand for low-skilled workers in this field; nevertheless, they are usually relocated to other production facilities within the company and are not as yet facing redundancy.

Welders' work is being continuously automated, primarily because of the higher reliability of welds performed by robots; and, secondly, because of their scarcity on the labour market, according to statistics.[5] Even though these workers might experience decreasing job opportunities in particular companies where the share of robots is growing significantly, welders are still professionals in demand on the labour market, especially those who are able to use different welding techniques. Nevertheless, our findings also suggest that task standardisation and automation have contributed to the relative deskilling of welders. This was highlighted in two Czech companies producing electronic components and fuel combustion engines. Both respondents observed

5. For instance, in Czechia in January 2020 there were 8,244 jobs for welders being offered by employers but only 867 registered welders were available in the register of the Employment office of Czechia (MPSV 2020, https://www.mpsv.cz/web/cz/analyza-poptavky-po-pracovni-sile-a-nabidky-pracovni-sily).

diminishing work opportunities for medium-skilled manual workers. 'We have difficulties in adequately remunerating these medium-skilled people and finding them appropriate positions in the company. Some of them have retrained as CNC machine specialists, and some of them remain in the control and repairs department, but some have been downgraded in their position. There is simply no position where they can show their skills' (trade union representative, Czechia).

Automation is undoubtedly affecting assembly line operators in automotive companies since the majority of the companies we visited have introduced robots and/or collaborative robots to their assembly lines. Despite many of these changes decreasing the number of workers required for specific tasks, this has not been mirrored in an overall decrease in the demand for workers. Furthermore, since assembly incorporates various tasks and positions, there is no clear trend in the transformation of working conditions. In some cases, workers have lost autonomy and their tasks have been deconstructed following the introduction of robots, whereas others have needed to learn new roles and gain a deeper understanding of new processes. The introduction of robots has also led to assembly workers being exposed to increased requirements for multi-tasking when responsibility for a longer fragment of the production line is assigned to them, but this does not result in their upskilling.

Painting is being rapidly automated in our companies, mainly because of the dirty and dangerous character of the activity. Nevertheless, a significant number of painters, who undergo lifelong learning because of new technologies and materials, are still required.

Maintenance technicians are an in-demand profession on the labour market as a result of the increasing number of machines being implemented in production. Additional training, and even increases in the requirements for formal education, are typical of these positions although, on the other hand, the standardisation of repair tasks arising from the introduction of new technologies may, in some cases, contribute to the deskilling of workers. However, the prevailing perception of such positions is that they are in high demand and require formal qualification at least at the level of secondary education.

The work of materials planning analysts is expected to be transformed significantly as a result of digitalisation and the implementation of artificial intelligence (AI) in resource planning. That is why their numbers might decrease in production, although the requirements for educational qualifications are likely to increase.

Among new positions identified in our interviews, one respondent mentioned the role of an 'electrician lite' category expected to be needed in the future in the assembly of electric cars. This role would encompass a more narrowly-defined skillset for electricians, but would not require full qualification of electricians. This might have significant impact on demand for electricians, formerly the most skilled among manufacturing workers. There is also increasing demand for various engineers and programming specialists.

Table 4 **Changing skills requirements and job opportunities**

Traditional occupations in the automotive sector	Minimum education level required	Observed changes based on interviews	Impact of automation on labour demand	Changes in educational requirements
Logistics assistant	Primary education (ISCED 1)	– If logistics is automated, the position disappears (workers mostly transferred to other low-skilled positions)	Decreasing	No changes
Welder	Upper secondary education (ISCED 3 + compulsory training)	– Welding being automated continuously; ongoing automation in lower tier suppliers – Many welders need to retrain or else experience deskilling	Expected to decrease, but currently in demand, driven by production increases	Increasing, because of various techniques applied in welding
Assembler	Secondary vocational education (ISCED 2 and 3)	– If assisting robots, limited value added – Decreasing physical demands of work – Decreasing error rates as a result of new technologies, facilitating the employment of lesser-skilled personnel – Increasing work pace – Increasing complexity of work because of increased variability of production – In some cases, the need to understand the basics of machine operation – Increasing importance of product quality checks	Expected to decrease, but currently in demand, driven by production increases	Increasing for more specialised positions BUT decreasing for ordinary operators in robotised workplaces
Paint technician	Secondary vocational education (ISCED 3)	– Automation has brought significant improvement in working conditions – Workers remain at the workplace or are transferred to other workplaces	Decreasing	Remaining the same or increasing, with more advanced positions in handling painting machinery
Maintenance technician	Secondary vocational education (ISCED 3 and 4); advanced positions also ISCED 5	– Predictive maintenance requires reskilling and retraining as there is a need for better understanding of maintenance (but, in some cases, technologies may make the work easier, especially if some maintenance tasks are standardised)	Increasing (because more machines are deployed in production)	Increasing (acquired through training and/or formal educational qualifications)
CNC operator/tool and die maker	Secondary vocational education (ISCED 3 and 4)	– Tool prototypes in 3D printing require new knowledge (mostly in OEMs) – Or require retraining on upgraded machines	Steady	Increasing (acquired through training)

Traditional occupations in the automotive sector	Education level required	Observed changes based on interviews	Impact of automation on labour demand	Changes in educational requirements
Materials planning analyst	University education (ISCED 6 and 7)	– Increased educational qualifications needed as a result of SAP (introductions of ERP) and expected AI elements implemented in planning	Decreasing	Increasing (acquired through training and/or formal educational qualification)
New positions				
'Electrician lite'	Post-secondary education (from ISCED 4)	– New category of 'electrician lite' needed if mass electric car production emerges	Expected to emerge	-
Engineering positions	From short-cycle tertiary education (ISCED 5)	– Creative new thinking expected – Importance of understanding possibilities and their effective implementation in practice	Increasing	Increasing (acquired through formal educational qualification)
Programming specialists	From short-cycle tertiary education (ISCED 5)	– Importance increases in coordinating all production functions, understanding processes, suggesting solutions	Increasing	Increasing (acquired through formal educational qualification)

Source: own compilation based on interviews and EASC report (2018)

Our observations tell us that educational requirements are changing for most of these positions and retraining is needed. However, the level of retraining provided is usually not enough to deliver an upgrading of workers' skills. Moreover, retraining policies in the companies in our sample differ significantly. At OEMs, retraining policies have been developed and offer opportunities to keep pace with new technologies and professional development but, in lower tier suppliers, depending on the training system present in the company, shop floor workers have either received short training on the use of a new machine or, sometimes, not even that: respondents in some companies (in Poland and Czechia) revealed that there is no time for training at all.

Interestingly, workers' access to reskilling and retraining is, based on our observations, highly dependent on the individual's cognitive skills and their interest in learning and their ability to learn: 'When someone´s task is robotised, he or she can attain training which will allow them to operate the machine at the basic level, but this still presupposes some interest in understanding new technologies by that worker' (employee in an OEM training facility, Czechia).

'This is difficult; much is dependent on the individual's cognitive skills and ability to learn. Otherwise, with new technologies, people are either required to learn new information or, if not, are increasingly becoming appendices to the machines' (tier one trade union representative, Czechia). This mostly relates to assembly positions where robotisation might lead both to upgrading and to downgrading. While the former is substantially possible, given individuals' interest in learning and a company's retraining schemes in practice, the latter may be observed in the case of older workers and among employees less interested in reskilling and/or retraining. 'Older people, but not necessarily inexperienced ones, are placed in these machine-feeding positions. You can see them there, where they are basically taking a rest while receiving the same wage as when they worked in a more difficult job position' (tier one trade union representative, Czechia). In general, trade union representatives perceived robotised workplaces offering 'machine-feeding jobs' as advantageous for workers and were not pushing for general retraining and reskilling; neither did they oppose these types of positions.

On the other hand, respondents reported increasing requirements for attained education by employees, basically in all the traditional positions recognised in Table 4. Interviewees in Hungary confirmed that workers need a deeper understanding of production processes. 'Operators today are not your grandfather's blue collar factory workers! There are more engineers on the shop floor than simple manual workers. To get hired, you would at least have to possess a general certificate of secondary education or, rather, a certificate of vocational education in automotive technology. You can find manual workers mainly in in-plant materials transportation and in machine loading, or elsewhere, in assembly firms.' Evidence from a Polish company suggests that workers in automated production are also facing an increase in responsibilities since they need to ensure production in more complex processes in which human error is much more costly.

Various managers also pointed out that a better skilled workforce is significantly lacking, although it is not always clear what employers mean by a 'better skilled'. In many cases, it might be simply the manual skills required on assembly lines although, regarding new technologies, some managers explicitly revealed that they need workers who are sufficiently educated as to recognise the possibilities of new technologies and to design their efficient implementation in production processes. Nevertheless, a lack of better skilled workers, in both senses, is considered a major obstacle to companies' upgrading. At the same time, in the companies we visited, incentives and complex reskilling and retraining schemes that would allow employees to 'upgrade' from low-skilled shop floor workers to a skilled workforce able to work with new technologies are missing. In our sample, in only one case in Poland have obsolete blue collar workers at an OEM been retrained to carry out office jobs. In general, this transition from shop floor to office jobs is scarce and retraining schemes do not encourage this form of transformation.

4. Trade union responses

The purpose of our interviews was also to understand trade union strategies at company level as regards the changing working conditions associated with automation and robotisation in workplaces. In our interviews, trade union representatives articulated the mostly positive impacts of automation while only a few revealed negative impacts on working conditions and workers' prospects. All the respondents had experience of the introduction of new technologies, in production in particular, although the extent of the experience obviously differed depending on their company's position in the production chain, with OEMs and tier one suppliers being leaders in implementation. Nevertheless, all trade union respondents perceived machines and robots as representing continuous improvements drawn from lean production processes and related to the production of new and upgraded products.

Given the dependent position in global production chains of local companies in all three countries, any new investment in equipment and in improvements to the production process was perceived by respondents as a confirmation of the company's intention to remain in the location and the ability of local management to propose changes and attain some level of upgrading. From this perspective, trade unions did not oppose the implementation of new technologies, nor did they question the changing working conditions of workers.

Moreover, the use of various robots, sensors and visualisations on assembly lines that are aimed at decreasing workers' error rates, but which also shrink their autonomy, were welcomed by our respondents. Trade union representatives interpreted automation and task standardisation as tools to help workers perform their work better. In the context of local remuneration systems, perfect work performance is an important issue for workers for whom, on average, twenty per cent of the wage is dependent on performance. At the same time, this positive attitude must be interpreted in the context of the severe labour shortages being experienced by companies in the automotive sector. Trade unions considered that the introduction of robots highlighted the increasing workloads to which the remaining workers were exposed as a result of absent colleagues.

Our research also revealed that trade unions possess limited rights of co-determination when it comes to the introduction of new technologies in our companies. Also, they gained only limited information from management about the intended changes. The majority of trade unions claimed they had the chance of information and consultation on changes with the management, but almost everywhere only following their own request and often after the decision had been made. Despite the ability to acquire knowledge of what is going on, this has a purely informative role and there is no possibility to reverse it through bargaining, while pressure in the form of protests and strike action has not been recorded so far.

For some trade unions, European works council meetings have proved to be a good source of information about future changes at global level although these, however, often remain confidential until actually implemented. Not only are trade union members not able to reveal this information beforehand, again, neither can they subsequently reverse it (e.g. if a global announcement on the introduction of technologies is announced, or when an announcement is made about planned redundancies in some locations).

As we have observed, trade unions have not thus far developed a comprehensive strategy on how to approach new technologies and workers' reskilling. Trade union representatives claimed that their primary role is to protect workers against lay-offs, while upgrading is not on their agenda either at sectoral or at company level. Up to now, trade unions have applied standard strategies to protect workers which encompass the management of redundancies through retirements and through voluntary leavers and, where involuntary lay-offs are inevitable, they try to apply careful and clear criteria. At the same time, they are paying increased attention to workers' protection in terms of the health and safety aspect of working conditions in the workplace, while paying limited attention to deskilling and retraining strategies at company level.

Interestingly, some of our respondents claimed that they do not want workers to be pushed towards reskilling, especially older people, i.e. of pre-retirement age, who compose a significant proportion of trade union members in many companies. In the case of younger people, they leave it up to individuals' decisions regarding their interest in retraining and their ability to benefit from it. Trade union leaders encourage the participation of selected individuals in retraining, but mostly those who 'seem to be capable', supporting the individual self-selection of workers for reskilling. As a result, trade union representatives do not recognise the need to conduct comprehensive training policies for manual workers at company level, nor do they demand that employers introduce them. At the same time, employers have proven to be reluctant to introduce any retraining and reskilling strategies into the collective agreement. According to our evidence, in only one OEM did a trade union propose this as a topic for collective bargaining, but it was unsuccessful.

What we have observed at company level is applicable to upper levels as well. When it comes to sector-level strategies on how to cope with employers increasing educational requirements and decreasing demand for manual labour, trade unions are not even involved in the discussion on strategies about the future of the automotive industry in their respective countries. The Action Plan on the future of the automotive industry for Czechia,[6] for instance, does not indicate any development strategies for current employees. The Plan addresses the transformation of education programmes in schools, based on the needs of employers, but the reskilling of workers already on the labour market is not even mentioned. Similar may be observed at company level, with employers expecting newcomers to be better trained than their current employees, while the training of employees is carried out at a level which allows them to keep pace with current technologies but which does not encourage them to upgrade once employed in the company.

5. Conclusion: Towards a policy response

Through our research in Czechia, Hungary and Poland we have gathered evidence which suggests that new technologies are having an impact on working conditions in terms of changing job opportunities and in job requirements. However, we did not observe them having any displacement effect, either at company or at sectoral level, mostly because of labour shortages in the region and increases in production capacities in many companies. Nevertheless, our research confirms the deskilling effect of the introduction of new technologies as regards manual workers, as well as the increasing demand for skilled workers.

Compared to the findings of a similar investigation by Matteo Gaddi into Italian companies presented in chapter 7 (see also Gaddi *et al.* 2018), our results suggest that workers and trade union representatives in CEE countries do not consider changes

6. (https://www.mpo.cz/cz/prumysl/zpracovatelsky-prumysl/automobilovy-prumysl/memorandum-o-budoucnosti-automobiloveho-prumyslu-v-cr-a-akcni-plan-o-budoucnosti-automobiloveho-prumyslu-v-cr---232552/ page 36, measure P3).

associated with the introduction of new technologies to be something which worsens working conditions even though, in Italian companies, the level of angst about new technologies is much more pronounced. It is important to relate this more limited perception of ongoing changes among our stakeholder interviewees to the context in which CEE countries find themselves. Here, the introduction of new technologies is perceived above all as an expression of the owners' intention to remain in the location, which is important for subsidiaries in the integrated peripheries of global production networks. Second, the motivation to invest in new technologies is driven by the lack of an available labour force which, again, contributes to an appreciation of the role of labour-saving technologies in production as well as to the lack of evidence of new technologies having a displacement effect in our companies. Third, the limited recognition of the negative impacts of the introduction of new technologies is blocking more critical appraisals and the creation of mitigation strategies at company, regional and national level. Moreover, in the Italian case, the increasing level of control over the tasks done by workers is pronounced and can be demonstrated with several detailed examples, while these aspects were mentioned only rarely by our respondents. This also suggests that there are different levels of advance in the introduction of new technologies between Italy and the companies in the countries we studied.

Trade unions have, up to now, not developed strategies to tackle the reskilling of possibly redundant workers. The only way that workers attain the upgrading of their skills lies in self-selection and individual plug-ins into company-level retraining. However, in the future, if workers are considered redundant, their prospects of reskilling will be determined only by their individual ability to seek retraining and to finance it if no policies at sectoral level, based on cooperation between employers and the involvement of public institutions, have been developed by that point. This might contribute to the further polarisation of job skills, leaving behind older workers, the less flexible and the young and inexperienced who might have difficulties in establishing retraining or reskilling opportunities.

The temporary circumstances concerning the labour markets of CEE countries are also contributing towards a postponement of policy responses regarding the introduction of new technologies. There is no effort to prevent structural unemployment because, for now (in 2019), very few people remain unemployed and thus the urgency of the need to conduct reskilling programmes is very low. Moreover, efficient retraining policies are simply not on the agenda of trade unions and other stakeholders. This comprises a striking question of the prospects for manual workers in the labour markets of the future in which digitalisation and automation will be highly developed and where jobs for many manual workers will have diminished. The expected consequence is that these workers will face unemployment with limited likelihoods of finding new jobs. Moreover, the COVID-19 pandemic may accelerate most of these processes and CEE region will face structural unemployment in very near future.

This might remind us of the similar development which CEE countries underwent in the 1990s, when the collapse of the Soviet Union caused a rapid increase in unemployment rates. The main cure that CEE countries applied at that time was to attract foreign investors who created low and medium-skilled manufacturing workplaces. Unemployment rates thereby decreased without any significant effort to encompass reskilling strategies, nor even to talk about industry strategies towards this. This, in turn, reduced the scope for public policies to deal with unemployment, confining this to the provision of support for foreign investors through generous state subsidies. However, in contrast to previous experience, an escape strategy in the form of foreign investors creating manual labour-intensive workplaces may not be available in the expected forthcoming wave of structural unemployment. Such changes will require more comprehensive strategies on how to bring the unemployed back to the labour market and this is something that actors in the CEE region will have to learn from scratch.

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