

<https://doi.org/10.20396/rbest.v3i00.15864>

DOSSIER: INDUSTRY 4.0

## Digitalization and change in the global division of labor: Industrial work in transition

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### Abstract

The article examines the extent to which the labor market is being squeezed by digitalization and automation processes, taking empirical material on the German automobile industry as its basis. The aim is to discuss three questions: (1) What dynamics of change in automation concepts can be observed, and what effects on the changing division of labor between high and low wage locations can be expected? (2) How are company location strategies, employment structures, and skill requirements changing, and what does this mean for production offshoring? (3) To what extent are industrial governance and international value chains changing as a result of the development towards data-driven business models? The article focuses on the transition taking place in the automotive sector. In addition to general statistical sources, the authors use a survey of works councils in auto supplier companies conducted in 2016.

**Keywords:** Automation; Automotive industry; Global value chains; Germany.

**JEL:** D20, J21, J31, L23, L62, O33.

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Editor's note: The original German version of this article was published as Krzywdzinski, M. (2019). Digitalisierung und wandel der globalen arbeitsteilung: Industriearbeit im wandel. In B. Kohlrausch, C. Schildmann, & D. Voss (Eds.), *Neue arbeit: neue ungleichheiten?* (pp. 88-109). Beltz Juventa.

## Digitalização e mudança na divisão global do trabalho: Trabalho industrial em transição

### Resumo

O artigo examina até que ponto o mercado de trabalho está sendo pressionado pelos processos de digitalização e automação, tomando como base um material empírico sobre a indústria automobilística alemã. O objetivo é discutir três questões: (1) Qual dinâmica de mudança nos conceitos de automação pode ser observada e que efeitos sobre a mudança na divisão do trabalho entre locais de altos e de baixos salários podem ser esperados? (2) Como estão mudando as estratégias de localização da empresa, as estruturas de emprego e os requisitos de qualificação e até que ponto existem perigos de externalização da produção? (3) Até que ponto a governança industrial e as cadeias de valor internacionais estão mudando como resultado do desenvolvimento rumo a modelos de negócios baseados em dados? O foco da argumentação é a transição que vem ocorrendo no setor automotivo. Além das fontes estatísticas gerais, é utilizado em particular um levantamento dos conselhos de trabalhadores nas empresas produtoras de autopeças, realizado em 2016.

**Palavras-chave:** Automação; Indústria automobilística; Cadeias globais de valor; Alemanha.

## Digitalización y cambio en la división global del trabajo: El trabajo industrial en transición

### Resumen

El artículo examina hasta qué punto el mercado de trabajo se está viendo afectado por los procesos de digitalización y automatización, tomando como base material empírico sobre la industria automovilística alemana. El objetivo es debatir tres cuestiones: (1) ¿Qué dinámica de cambio en los conceptos de automatización puede observarse y qué efectos en el cambio de la división del trabajo entre lugares con salarios altos y bajos cabe esperar? (2) ¿Cómo están cambiando las estrategias de localización de las empresas, las estructuras de empleo y las necesidades de cualificación y hasta qué punto existen peligros de externalización de la producción? (3) ¿En qué medida están cambiando la gobernanza industrial y las cadenas de valor internacionales como resultado de la evolución hacia modelos empresariales basados en datos? El argumento se centra en la transición que se ha producido en el sector automovilístico. Además de las fuentes estadísticas generales, se utiliza en particular una encuesta de los comités de empresa en las empresas productoras de autopartes, realizada en 2016.

**Palabras clave:** Automatización; Industria del automóvil; Cadenas de valor mundiales; Alemania.

## Digitalisation et changement dans la division mondiale du travail: Le travail industriel en transition

### Résumé

L'article examine dans quelle mesure le marché du travail est mis à mal par les processus de numérisation et d'automatisation, en s'appuyant sur des données empiriques relatives à l'industrie automobile allemande. L'objectif est de discuter de trois questions: (1) Quelles dynamiques de changement dans les concepts d'automatisation peuvent être observées et quels effets sur l'évolution de la division du travail entre les lieux à hauts et bas salaires peuvent être attendus? (2) Comment les stratégies d'implantation des entreprises, les structures d'emploi et les besoins en compétences évoluent-ils et dans quelle mesure l'externalisation de la production présente-t-elle des dangers? (3) Dans quelle mesure la gouvernance industrielle et les chaînes de valeur internationales changent-elles en raison de l'évolution vers des modèles d'entreprise axés sur les données? L'argument est centré sur la transition qui s'est opérée dans le secteur automobile. Outre les sources statistiques générales, on utilise notamment une enquête sur les comités d'entreprise des sociétés productrices de pièces automobiles, réalisée en 2016.

**Mots clés:** Automatisation; Industrie automobile; Chaînes de valeur mondiales; Allemagne.

## Introduction

There are various expectations of the effects of digitalization on the global division of labor in the current debate. First, there are scenarios that primarily understand digitalization as a new run-up to automation (Boston Consulting Group, 2016; Ford, 2015) which will translate into significant productivity gains. This is linked to the hope that manufacturing plants in high-wage countries will become more competitive and production that has already been relocated to low-wage countries will return to high-wage locations (Ford, 2015; Bundesministerium für Wirtschaft und Energie [BMWi], 2016). However, the employment effects of such a development are not clear. Automation could lead to employment losses, but the relocation of production could also lead to employment gains.

Second, studies indicate that digitalization also leads to the standardization and objectification of processes and knowledge, strengthening the globalization of companies and value chains (Ernst, 2005). This could accelerate the relocation of production from Germany to low-wage countries, threaten employment, and put pressure on wages.

Third, digitalization is also seen as a process which undermines traditional forms of organization (Jürgens, Hoffmann, & Schildmann, 2017; Schröder, 2016). New forms of online-based work threaten to undermine traditional employment relationships embedded in organizations, leading to the erosion of labor standards and a decrease in the reach of collective agreements, trade union representation, and co-determination. A polarization could develop between a shrinking core of traditional and secure employment and a growing fringe of precarious work, as is already being discussed in the context of the spread of temporary work and work contracts. Crowdwork, the organization of work with platforms that organize so-called crowds of solo self-employed workers, is considered an important phenomenon in this context. However, opposite dynamics are also conceivable here. Particularly in the phase of increased product and process innovation, currently experienced as digitalization, the importance of direct communication and cooperation “under one organizational roof” could both increase and counteract the tendencies outlined above.

Fourth, the discourse around globalization addresses changes in industrial governance related to the increasing importance of data as the basis of business models. The successful business models of the future are expected to be based primarily on the mastery of data and its analysis, while the (physical) processes of product development and especially production will lose their centrality to corporate success (Bitkom, 2017). As a result, traditional sector boundaries between industry and software or industry and services are increasingly dissolving. New competition for position as lead firms, and thus for the

governance of value chains in traditional sectors, is emerging. The dominance of US companies in the area of data-based business models has led to fears that Germany could become an extended workbench of Silicon Valley as a supplier of hardware, while American IT companies take control of the value chains (Keese, 2014).

Against the background of these different scenarios, this article examines the extent of pressure to the labor market from digitalization and automation. In particular, we focus on three questions, using empirical material from the automotive industry:

- 1) What dynamics of change in automation concepts can be observed, and how are these expected to change the division of labor between high-wage and low-wage locations?
- 2) How are company location competences, employment structures, and qualification requirements changing?
- 3) To what extent are industrial governance and international value chains changing as a result of developments towards data-based business models?

The article builds on several research projects conducted at the Social Science Centre Berlin (WZB) (Krzywdzinski, 2019). The focus is on the automotive industry. The article uses the survey of works councils in automotive supply companies conducted in 2016, in addition to general statistical sources. 142 works council chairpersons from companies in Baden-Württemberg, Bavaria, and North Rhine-Westphalia – the central automotive regions in Germany – took part in the survey (for detailed information on the survey, see Krzywdzinski, 2016).

The article is structured as follows. In section 1, the dynamics of automation and associated changes in the global division of labor are analyzed. The development of location skills and employment structures in industrial firms is discussed in section 2. Section 3 examines the move towards data-based business models and the potential impact on the global division of labor. The final section includes overarching conclusions.

## **1. Automation, offshoring, and reshoring**

Does greater use of technology in manufacturing offer high-wage countries like Germany the chance to increase productivity and regain manufacturing capacity relocated to low-wage countries? This is one prediction in the current discourse around Industry 4.0. Industry 4.0 approaches primarily focus on the development of cyber-physical systems; systems of machines and components networked on the basis of the Internet of Things, to which the property of self-regulation is attributed (Spath, 2013; Forschungsunion & Acatech, 2013). Industry 4.0 is also, however, often understood as automation (Boston Consulting

Group, 2016). The German Ministry of Economics views Industry 4.0 as an opportunity to shift industrial jobs back to Germany (BMW, 2015, April 13). In its ten theses on Industry 4.0, the Fraunhofer Institute for Systems and Innovation Research (Fraunhofer ISI) also proclaims the opportunity for a recovery of industrial production shifted to low-wage countries for cost reasons, even while addressing the danger that digital networking will make it easier to relocate R&D (research and development) and production (Reiß, 2015, p. 10).

Adidas' Speed Factory is often cited as an example of the relocation of production from Germany to low-wage countries. Adidas long ago relocated the production of shoes to countries like China. The Speed Factory in Germany was a remarkable change from the previous policy. It produced highly automated personalized shoes using 3D printing technology. However, despite the start of mass production in 2017, only a fraction of Adidas' total shoe production is manufactured there; 97% of shoes are produced using traditional methods in Asia (Welt, 2017, August 20). Moreover, the Speed Factory in Germany was closed in 2020 and has remained a prominent but isolated case. Empirical studies (cf., for example, Krzywdzinski (2016) for the automotive supply industry) do not provide evidence of a general trend towards relocation.

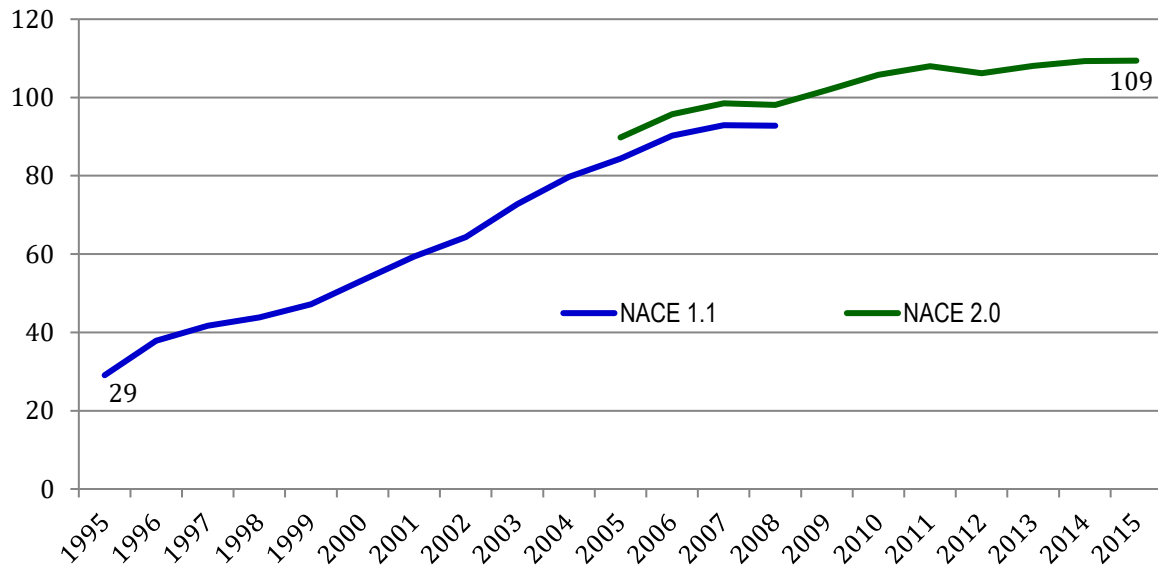
There are two arguments against a reversal of previous trends in the global division of labor. First, even in high-wage locations – apart from a few model projects such as the Speed Factory – there has so far been no major push in the area of automation. This is not least because industry in these locations is already characterized by a very high degree of automation. End-to-end automation and digitalization has long been the case in process industries such as the chemical industry. But in piece-goods industries such as automotive suppliers, about 54% of companies report a strongly or predominantly automated production; in 36% of companies, production is characterized as mixed, consisting of automated and predominantly manual areas, while only 10% of companies still have a predominantly manual production (Krzywdzinski, 2016).

Ongoing pilot projects, experiments, and the first systematically implemented Industry 4.0 solutions, show that the importance of automation is overestimated in the public debate. In many cases, new forms of networking and data collection and use are of more importance than the replacement of human labor with computers or robots (Butollo, Jürgens, & Krzywdzinski, 2019).

Figure 1 shows that the development of automation in the German automotive industry was a gradual process that took place over a long period of time. This is illustrated here with the example of industrial robots, though it should be noted that robot use is only one aspect of automation. The growth in robot use has slowed in recent years compared to the 1990s when a much faster increase in automation was observed. This is because the

main area of application for industrial robots is car body construction, which already has automation levels of over 90%.

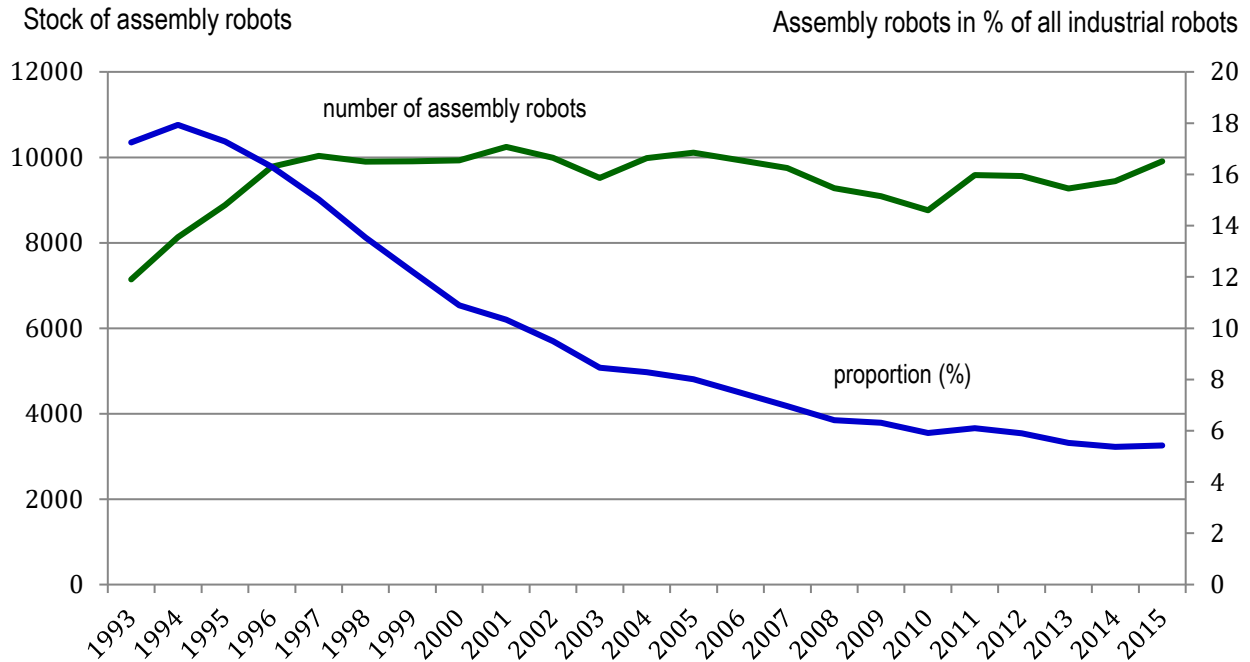
**Figure 1**  
**Number of industrial robots per thousand employees**  
**in the German automotive industry, 1995-2015**



Source: Eurostat sbs\_na\_2a\_dfdn and sbs\_na\_ind\_r2; International Federation of Robotics, World Robotics 1.1.14. Due to a change in industry statistics, figures are shown according to NACE 1.1 and according to NACE 2.0.

By contrast, assembly areas in industrial plants have hardly been automated, and are still characterized by manual work. An important innovation in the context of Industry 4.0 are the so-called “collaborative” robots (cobots) which can be used flexibly, and whose price has fallen massively in recent years. However, this is still a niche phenomenon. So far, cobots have been used either in simple auxiliary functions (sorting parts, packaging, reloading) or in narrowly defined areas where very stable process conditions can be created. In these areas of application, the cobots take on tasks that are particularly repetitive or ergonomically unfavorable for humans. They are, therefore, more of a sensible improvement in working conditions than a systematic threat to employment. In many other assembly areas, however, stable conditions for the use of cobots cannot be guaranteed due to spatial conditions, the diversity of parts and variants, and the volatility of the manufacturing process. Accordingly, as shown in Figure 2, there has been no increase in the number of assembly robots in Germany since the 1990s, and the share of assembly robots in the total stock of industrial robots is decreasing (see also Krzywdzinski, 2021).

**Figure 2**  
**Assembly robots in Germany, 1993-2015**



Source: International Federation of Robotics, World Robotics 1.1.14.

So even if automation does not play a central role in Industry 4.0 concepts, it can be expected that networking and data use in manufacturing could enable efficiency gains, increasing the competitiveness of high-wage locations. However, it is important to note the so-called “productivity paradox” of Information Technology (Brynjolfsson, 1993). There has long been a discussion in economics that, contrary to all expectations, the introduction and diffusion of IT does not seem to have any effect on productivity development. This was emphasized by the recent study by MIT researchers with Daron Acemoglu and David Autor (2014). Peter Brödner (2008) argues that this paradox is due to the nature of IT. Information technologies are essentially concerned with the processing of information, and their goal is to support action processes in organizations. IT only contributes to increased productivity if there are organizational structures and processes that make this possible; people translating digital information into knowledge and action through communication and interaction. Productivity leaps are only possible where IT is combined with organizational innovations.

The second argument against an expectation of massive relocations back to high-wage countries is the high pace of globalization of process technologies within multinational corporations. In the well-established low-wage locations in Central Eastern Europe – though

this also applies to many factories in China – so-called lead plants, where new technologies are tried out and brought to series maturity, often have a technological lead of only a few years before a technology is used globally (Krzywdzinski, 2016). In addition, lead tasks are also increasingly outsourced to factories in low-wage regions. This is particularly the case in the automotive supply industry, where the customers – car manufacturers – exert considerable influence on location and technology decisions, pushing very strongly for the use of low-wage locations. Not least due to the networking between car manufacturers, suppliers, and logisticians, it is also conceivable that Industry 4.0 technologies will also facilitate just-in-time delivery over greater distances, further strengthening low-wage locations.

The technological catch-up process in low-wage countries is strengthened by programmes such as “Made in China 2025” (MiC2025) in China. This government programme channels considerable public and private investment into the development of the digital economy and, in particular, the digitalization of industry. Lüthje and Butollo (2017) argue that MiC2025 is a comprehensive project of transforming the Chinese economy, supporting companies in a wide range of mid- and high-tech industries in developing data-based business models, building digital infrastructures, and developing new digitalization concepts for work processes. In the industrial sector, the aim is to increase the competitiveness of companies, against the backdrop of rising wages and increasing labor shortages (Lüthje & Butollo, 2017, p. 49).

A further shift of production to low-wage locations could also be promoted by a technological development, that while a core element of Industry 4.0, is not related to automation; the increasing use of digital assistance systems in the area of factory management in assembly and logistics, but also in the area of higher-skilled activities such as maintenance. Digital assistance systems are programmes for guiding and supporting work operations that can be used by employees on tablets, monitors, data glasses (wearables – technologies worn on the body) or other devices. So far, there is relatively little empirical evidence on the prevalence and types of use of digital assistance systems. Existing studies mainly emphasize the control possibilities opened up by the new technologies. Reports on the use of data glasses at Tesco and Amazon show that productivity data, movements, and interactions of employees are recorded and evaluated (Rawlinson, 2013, February 13; Moore & Robinson, 2015).

There are also still no systematic findings on the effects of digital assistance systems on work organization and qualification requirements (Butollo, Jürgens, & Krzywdzinski, 2019). However, experiences from the logistics sector illustrate the dangers of increased standardization of activities and the reduction of qualification requirements. So-



called pick-by-vision concepts are becoming increasingly popular in logistics and tie in with already proven pick-by-voice and pick-by-light approaches. In the newer concepts, logistics workers wear data glasses connected to the order management system. The order management system provides the information on which products are needed, where they are in the warehouse, and in which order they have to be picked. All the information and instructions are displayed step-by-step on the data glasses. The camera built into the data glasses or the RFID chips worn on the body confirm that the correct products have been picked up. Digital control of the work process is very far-reaching. If such technologies become widespread, some authors fear the “Amazonization of industrial work” (Butollo, Ehrlich, & Engel, 2017).

The first projects introducing digital “worker guidance” concepts are also underway in manufacturing, especially in assembly areas. These can take the form of permanently installed screens on which workers receive information and instructions in the work process. But there are also ambitious projects testing movement control approaches. The MotionEAP project funded by the Federal Ministry for Economic Affairs and Energy (2016) aimed to develop sensor- and camera-based control systems that immediately detect errors and problems in the work process. In such cases, a warning was displayed at the workplace via a projector. The goals of the project went far beyond movement control: The facial expressions of the workers were analysed to recognize stressful situations.

Certainly, the developments outlined here are still in their infancy. But they certainly hold the potential for further standardization and de-skilling of assembly work, which in turn could increase the scope for relocation and offshoring. Manufacturing and assembly processes, currently at high-wage locations because of qualification requirements, could thus become at least somewhat feasible at low-wage locations with low-skilled workforces.

## **2. Offshoring? Employment and skills development in industrial companies**

The thesis of increasing dissolution of traditional organizational forms is often formulated when discussing the transformation of value chains through digitalization (Ittermann, Niehaus, & Hirsch-Kreinsen, 2015; Schröder, 2016; Jürgens, Hoffmann, & Schildmann, 2017). The company is the focus of the regulation of labor to date; it is where the employment relationships are located and the co-determination rights defined by the German Works Constitution Act are exercised. For some time now, there has been a tendency to shrink the company core and outsource tasks and work processes to organizational forms that escape company labor regulation, such as through outsourcing or

the use of temporary agency work and contracts for work and services (Promberger, 2012; Hertwig, 2015). Digitalization, it has been argued, exacerbates this process, dissolves organizational boundaries, and distributes work processes modularly across the globe (Brown, Lauder, & Ashton, 2011, p. 76). The consequences for labor standards and social security systems would be serious.

This fear is not new. Since the 1990s, digital technologies have made teleworking, cooperation in virtual teams, and, in particular, global outsourcing possible. Current worries about digitalization relate primarily to the phenomenon of crowdwork (Benner, 2014). Crowdwork is a new form of work in which internet-based platforms organize a large number of formally independent crowdworkers, distribute tasks and orders to them via the internet, and also take over quality and performance control (Gerber & Krzywdzinski, 2019; Leimeister & Zogaj, 2013). Crowdwork gives rise to new employee-like roles which are not covered by traditional concepts of enterprise and employee. The regulatory scope of the enterprise is shrinking and there is a discussion about the extent to which legal framework conditions need to be adapted, for example, by expanding the concept of the enterprise and the protection and co-determination rights, or by creating new regulatory mechanisms for network-like structures (Däubler, 2015).

The scale of the crowdwork phenomenon must be put into perspective. While platforms registered in Germany have hundreds of thousands of registered crowdworkers, many are only occasionally active, or earn only small incomes that supplement other sources of income. According to a study by Leimeister, Durward, and Zogaj (2016), only about 30% of crowdworkers earn more than 500 euros per month. Case studies of crowdwork platforms by Gerber and Krzywdzinski (2019) suggest that only about 5-10% of registered crowdworkers are regularly active on the platforms, working on orders. However, exact figures are lacking on the size of the crowdwork phenomenon.

The growth of crowdwork has not led to the dissolution of traditional companies. Despite the quantitative growth of this form of work, the scope of application is very limited (Al-Ani, Stumpp, & Schildhauer, 2014). The areas of activity most frequently organized as crowdwork include text production for websites and data categorization (so-called microtasks), and design and programming (macrotasks). From the perspective of industrial companies, these are mostly support activities for the marketing, sales, and engineering departments. Crowdwork has been used in the automotive industry in the categorization of images to develop image recognition algorithms used in autonomous driving, and the updating of data for marketing and sales. This undermines neither the existing white-collar and engineering sectors in companies, nor the operational organization of manufacturing processes, as crowdwork is not found in the manufacturing sector. Crowdwork is often used

for tasks that could not be sensibly processed in the past, such as the categorization of millions of images.

So there is little evidence of a dissolution of traditional organizational forms, especially in the industrial sector. Certainly, today's companies operate in networks and production is organized as a network of actors, including equipment suppliers, suppliers of different levels, service providers, and the final manufacturers (Sydow, Schüßler, & Müller-Seitz, 2016). Companies have for some time now combined the so-called "core workforce" with a larger "fringe" of precarious employment. However, previous experience and developments suggest that this need not lead to a questioning or even a dissolution of the company. The organization of most work processes still requires considerable communication and face-to-face cooperation, and product development, planning, and manufacturing processes can not be spatially separated indefinitely, maintaining the importance of company structures.

The rapid pace of innovation in the context of digitalization is even increasing demands on operations. A network of actors are responsible for the development and implementation of complex Industry 4.0 solutions, but companies must be able to absorb and process the knowledge that arises in the process (Heidenreich, Kädtler, & Mattes, 2016; Boes, 2003; Calabrese, 1999). Lazonick (2005) emphasized that innovation processes presuppose certain social conditions, such as the integration of different actors, the avoidance of opportunistic behavior, and the promotion of collective learning. For manufacturing companies, this means intensive cross-functional cooperation between product development, process engineering, logistics, and production. Implicit experiential knowledge, the establishment of a common understanding, and the development of routines and rules of action for practice remain the central prerequisites for the implementation of new technologies, and they must be developed jointly by the different actors involved in the company (Pfeiffer, 2016).

So there are advantages to the company retaining a central role, at least for most work processes. A closer look at historical developments shows how companies have changed during the process of digitalization. The last few decades have seen a specialization process in German industry in which factories increasingly take on lead roles for the introduction of new products and production technologies. This development has been driven by the accelerated globalization of German industrial firms since the early 1990s. The development of global production networks made it necessary to develop plants with special lead and support tasks for the overall network. German plants were able to draw on their long experience, but were also forced to develop further by competition from new locations in low-wage countries. The low-wage factories have undergone an upgrading process in the

last twenty years in which their technologies, products, and organizational structures have been modernized (Jürgens & Krzywdzinski, 2010). Their productivity and quality are converging with established plants in high-wage countries (Herrigel, Voskamp, & Wittke, 2017), putting the latter under increasing pressure to relocate. Long-term location and employment security at high-wage locations is only possible if they take on innovation functions and lead plant roles, mobilizing their special experience and knowledge stocks (Schwarz-Kocher, Korflür, & Krzywdzinski, 2019).

A core component of this specialization is the assumption of lead roles in the introduction of new products and production technologies. Research on product development processes has shown that cooperation between product development and manufacturing (as well as other company divisions such as planning and procurement), from the beginning of the development of the product to series production, is of central importance to ensuring that the products can also be produced at reasonable costs (Clark & Fujimoto, 1991; Jürgens, 2000). The need for cross-functional cooperation also remains during the product ramp-up phase. Here, potential problems with the product specification and “manufacturability” of a product are uncovered. Potential problems in the design of production processes and the functioning of production technologies also become apparent. Mastering the production ramp-up and cooperating with product development and other functional areas requires a very experienced and highly qualified workforce, which not all plants have (Fjällström et al., 2009; Jürgens, 2000).

**Table 1**  
**Roles of German and Central Eastern European manufacturing plants of automotive suppliers.**  
(data in % of the plants surveyed)

	Country / region	Always or mostly	Sometimes or partially	Never or rarely
The products of the latest generation start first in our plant	Germany	48.4	37.1	14.5
	CE Europe	27.2	53.3	19.6
New production technologies are first tried out in our plant	Germany	43.9	39.0	17.1
	CE Europe	20.8	52.1	27.1
Our facility is responsible for supporting other sites with product ramp-up	Germany	58.1	27.4	14.5
	CE Europe	30.9	40.2	28.9

Source: Own representation based on Krzywdzinski et al. (2016).

Note: Workplace employee representatives in 142 German and 125 Central Eastern European automotive supply plants were surveyed.

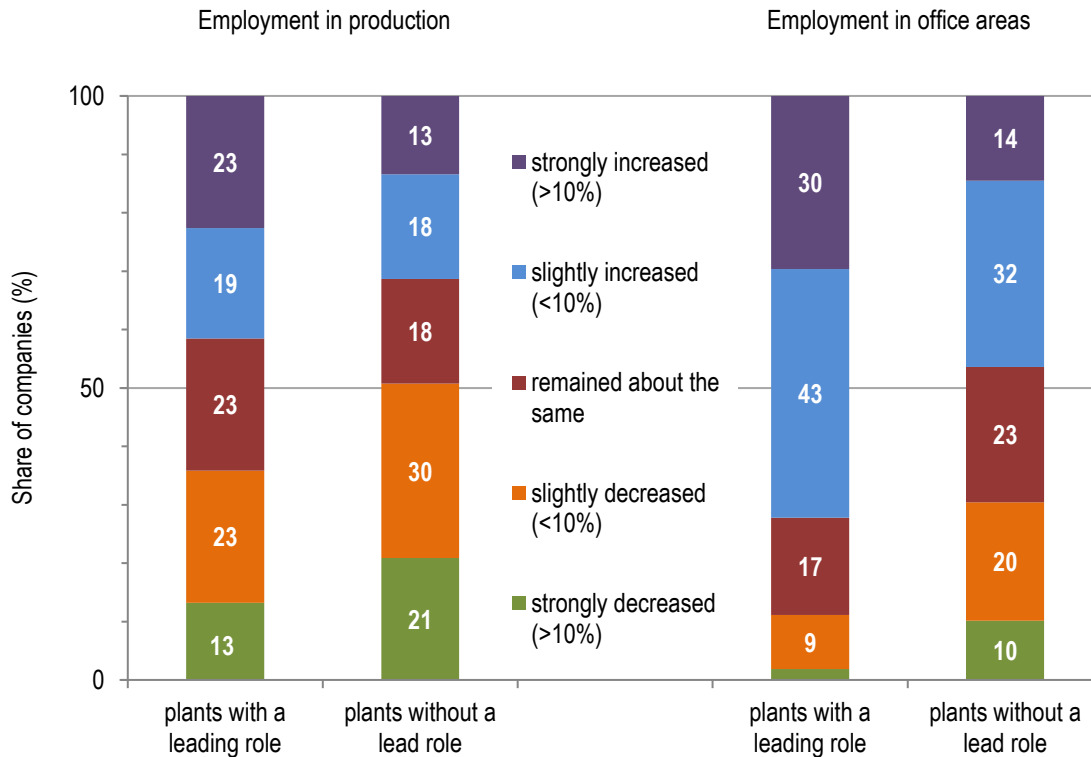
The strength of German plants in taking on such lead plant roles is illustrated by the survey of works councils in the automotive supply industry presented in the introduction. Central Eastern Europe is an interesting reference point for the analysis of German plants; plants there have undergone a remarkable upgrading process and are among the strongest competitors of German plants (Jürgens & Krzywdzinski, 2010). As Table 1 shows, about 40-50% of German plants are permanently responsible for the introduction of new products and production technologies, while this applies to 20-30% in Central Eastern Europe. German plants also continue to play a central role within global production networks, taking over support tasks for other plants during product launches.

This specialization of German plants in lead plant roles is expected to increase, due to the ongoing competition with low-wage countries and the testing of Industry 4.0 concepts. Pure manufacturing plants lacking in innovation and lead plant functions are faced with relocations and job cuts in competition with low-wage locations. However, for plants that play a leading role in the introduction of new products and technologies, Industry 4.0 concepts could open up opportunities to extend the lead over low-wage locations and secure employment. It is therefore expected that the development of German manufacturing plants with regards to digitalization will be characterized less by processes of erosion, and more by a pressure to strengthen the ability of companies to innovate and take on leading roles in the implementation of new products and production technologies.

This development will have consequences for employment, but will not lead to a widespread reduction of employment in industry, such as that predicted by the OECD (2017) or by well-known studies such as that of Frey and Osborne (2013). The latter authors have had great media coverage with their forecast of the automation of 47% of US jobs in the medium term.

Based on developments to date, it is more likely that the importance of skilled labor will increase. Looking at workforce structures in manufacturing plants again using the survey of works councils in the automotive supply industry in Germany, in plants with a leading role in the introduction of new products and production technologies, production employment has been stable in recent years, while office employment has been rising (Figure 3). This definitely demonstrates a shift in the employment structure, but not a loss of manufacturing employment in absolute terms. In plants without a lead role, however, employment in production has fallen slightly on average (median), while employment in white-collar sectors has remained stable. This is an expression of the stronger competitive, relocation, and rationalization pressures to which pure manufacturing plants without additional innovation roles are exposed.

**Figure 3**  
**Employment developments in German automotive supply plants**  
**with and without a lead plant role, 2011-2016**

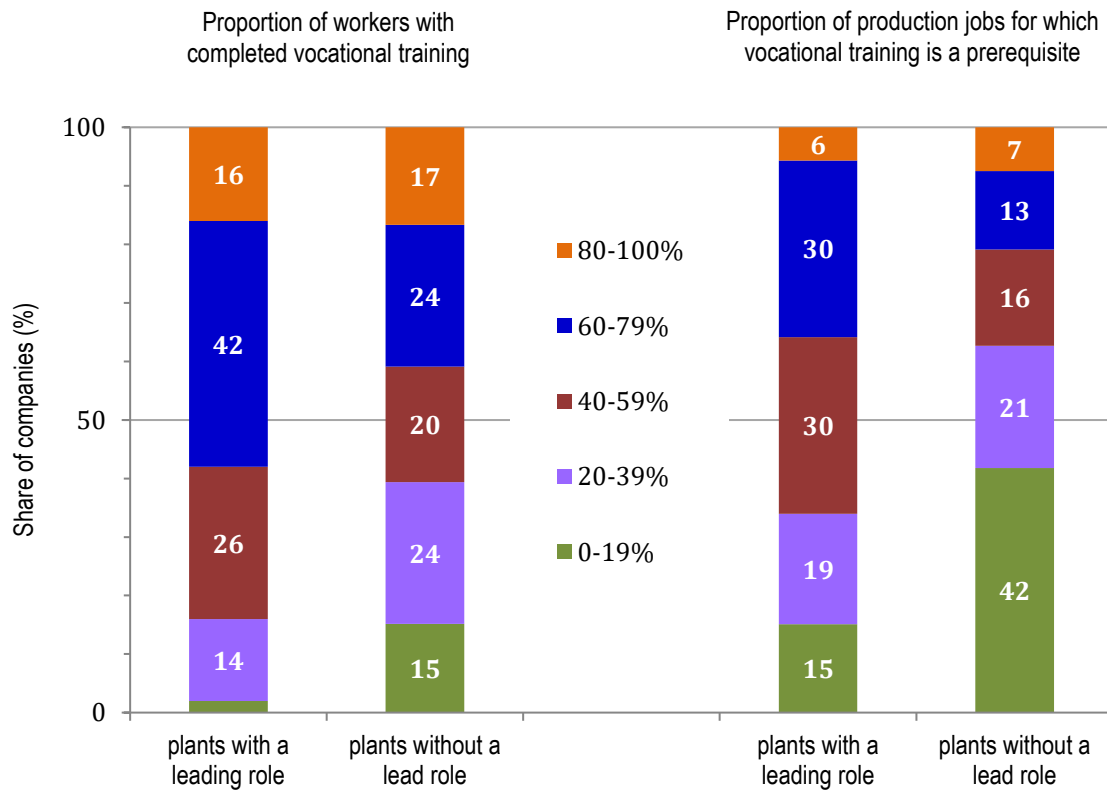


Source: Krzywdzinski et al. (2016).

Note: Mann-Whitney Test 0.0923 (employment production) and 0.0015 (employment office sectors).

The development of German industrial companies can be interpreted as a continuous specialization in tasks related to innovation, and in lead roles in the introduction of new products and technologies. Employment in plants with lead roles is rising, while in plants without such roles it is falling or stagnating. This development also entails a shift in the skill structures in German industry, with an increasing share of highly skilled workforces (Figure 4). As Figure 4 shows, plants with a lead plant role have highly skilled workforces in production. In an average (median) plant with a lead role for the introduction of new products or technologies, 60-79% of production workers have completed vocational training, compared to 40-59% in an average plant without a lead role. The proportions of jobs where vocational training is really required are somewhat lower, but here too there are clear differences between the two types of plants. In an average plant with a lead role, vocational training is assumed as necessary for 40-59% of production jobs; in an average plant without a lead role this is the case for 20-39% of the jobs.

**Figure 4**  
**Workforce structures in production in German automotive supply plants with and without a lead plant role, 2016**



Source: Krzywdzinski et al. (2016).

Note: Mann-Whitney Test 0.0316 (shares of workers with vocational training) and 0.0023 (shares of jobs).

Incidentally, that the proportion of workers with vocational training is higher than the proportion of jobs for which vocational training is a prerequisite points to surplus skills stocks in German manufacturing companies. In many industrial companies, employees with specialized training also work in production jobs that do not require specialized training. Their skills are not systematically utilized, and contribute rather unnoticed to the problem-solving ability of the production workforce. These surplus qualifications are an advantage for German factories, especially with regard to the implementation of new production technologies, compared to low-wage regions where the recruitment of skilled workers for production is becoming increasingly difficult (Krzywdzinski, 2017; Jürgens & Krzywdzinski, 2015). Overall, this suggests a long-term trend of the growing importance of vocational skills and an upskilling of industrial employment.

### 3. Data-based business models and changes in industrial governance

Process innovations in Industry 4.0 have a rather gradual character. There is indeed profound change, but this change is slower than suggested in the public discourse, and represents a continuation rather than a break with previous developments. Significantly however, more radical changes in the global industrial division of labor could initiate product innovations in the short and medium term, especially the development towards data-based business models.

Such business models are based on the control and evaluation of data bundled into a new product. There are many examples of the increasing importance of data-based business models. The American company Uber has shown that it is possible to offer mobility services based on data alone, without owning a fleet of vehicles or even hiring drivers (De Stefano, 2016). One example from the field of mechanical and plant engineering is wind turbines (Wieselhuber & Fraunhofer IPA, 2015, p. 28). The more profitable business model of the future might not be the sale of wind turbines, but the sale of a certain turbine *output*. A company that specializes in the control and optimization of wind turbines, mastering the networking of the turbines and the analysis of turbine data, could sell such a turbine output as a product. The classic wind turbine manufacturers would become pure hardware suppliers to this new company and lose the interface to end customers. The development of data-based business models will thus shift classic industry boundaries between mechanical engineering or manufacturing companies in general, and the IT and software sector. The Federation of German Industries (BDI) emphasizes that this change could also give non-industry providers with expertise from the software sector a new significance:

It is also within the realm of what is already possible today for data aggregators to gain new insights into material wear or maintenance intervals and to monetize them. The competition is often not won by the more convincing concept, but by whoever builds up a network the fastest (Roland Berger & BDI, 2015, p. 19, our translation).

A number of authors argue that the rise in importance of data-based business models is an expression of a structural shift towards a platform economy (McAfee & Brynjolfsson, 2017; Kenney & Zysman, 2016; Kushida, Murray, & Zysman, 2015; Gawer & Cusumano, 2014), and that traditional industrial companies are ill-equipped for this shift. Accordingly, they could soon be challenged in their product markets by competitors from the software sector and lose their customer interface (Roland Berger & BDI, 2015; Wieselhuber & Fraunhofer IPA, 2015).



However, the competition for control of industrial value chains is definitely open. In many areas, long established industrial companies are among the innovation drivers, though they may use organizational forms from the software industry and spin off new business areas, providing them with the necessary mobility and independence from the parent company. In Industry 4.0 software platforms, traditional industrial companies, such as Siemens, Bosch Software Innovations (SI), Freudenberg IT and Trumpf (Axiom platform), have a strong position in the market. These companies offer solutions that enable the networking of plants, performance management, and analysis of production data (such as configuration of systems, control of machine running times and downtimes, evaluation of production data and virtual real-time image of production, and predictive maintenance), remote maintenance, and remote service. Industrial companies are clearly able to competitively advance into the market for Industry 4.0 software solutions, harnessing accumulated knowledge and long-term relationships in the network of production equipment suppliers, manufacturers, and service providers. Fundamental shifts in the lead firms of industry and the control of value chains have not yet been observed.

## Conclusions

The impact of digitalization on the world of work is still unclear. This process is shaped by different partly contradictory forces and trends, and we are still in a phase of experimentation and competition between different design solutions. We are also still at the beginning in researching the current digitalization phase. Nevertheless, development trends can be identified that contradict some arguments that are widespread in the scientific and public discussion.

First, it should be emphasized that the perception of Industry 4.0 (or more generally of digitalization) as a new automation start-up cannot be confirmed, based on the development trends in industry to date. There is a focus on the development of cyber-physical systems, the networking of production, and “smarter” manufacturing organization through Big Data analyses and other data evaluation procedures. To what extent these will lead to automation at a later stage is still open. Hopes that Industry 4.0 concepts will increase the productivity and competitiveness of high-wage locations through automation, leading to a return of previously relocated production volumes, are accordingly still speculative. So far, there has only been a small number of such reshoring cases. The observation of a very rapid global diffusion of process technologies does not imply a comprehensive relocation. Meanwhile, increased efforts towards technological upgrading and

automation can also be observed in low-wage locations; China's MiC2025 programme is the most prominent example.

Forecasts of dramatic short- and medium-term employment losses due to automation seem implausible, even if they are repeatedly and vehemently put forward in public. However, hopes of relocating production back from low-wage countries also seem implausible.

The empirical analysis also suggests caution with regard to scenarios of a short- and medium-term erosion of traditional organizational forms and industrial employment in general in high-wage locations. On the contrary, innovation requires close integration of organizational processes and nodes where communication and cooperation are bundled. Over recent decades, many German manufacturing plants have become such nodes, and have specialized in leading roles in the introduction of new products and new production technologies in the global competition for locations. Certainly, today's digital technologies enable further outsourcing and offshoring of tasks (to crowdwork platforms, for example) and an increase in project-based forms of organization in which employees in different countries, companies, and locations work together. However, such outsourcing of tasks and processes has been going on for a long time and has not led to the disappearance of traditional forms of organization.

With regard to workforce structures, the past specialization of German manufacturing has meant a tendency towards upskilling, with an increase in the share of highly skilled employees both in the white-collar and blue-collar sectors (primarily in the form of completed vocational training). This tendency contradicts scenarios of polarization which predict a shrinking of occupational groups with medium skill levels; highly skilled knowledge work and non-automatable simple manual work remain stable or grow. However, polarization of pay structures can arise if German manufacturing plants without lead plant functions and special innovation-related tasks resort to low-road strategies, deviating from collective bargaining standards via site protection agreements or dropping out of the collective bargaining system altogether (Haipeter, 2010).

In contrast, it is currently very difficult to predict the potential impact of data-based business models and platform strategies on industrial governance and the control of value chains. Scope to enter the market is opening up for new competitors from the IT, software, and internet sectors. However, some of the traditional industrial companies are proving to be quite innovative in the development of data-based business models, such as new software platforms for Industry 4.0. The outcome of the competition is still open.

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