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Hartmut Hirsch-Kreinsen

DIGITALISATION AND LOW-SKILLED WORK

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FOREWORD

In 2013 the low-skilled accounted for 23 percent of the German workforce. Low-skilled work, generally done by workers with few qualifications, is thus clearly an integral component of modern industrial production. In the current "Industry 4.0" discussions about mechanising, automating and digitalising the entire world of work, low-skilled work and repetitive tasks are treated as increasingly anachronistic relics from the early industrial era. It is suggested that within just a few years there will be no industrial jobs left for the unskilled and semi-skilled, leaving many workers facing social exclusion and loss of status.

In fact, talk of a general erosion of low-skilled work is premature. Over the past fifteen years this type of work has actually stabilised, after industrial rationalisation processes broadly reached their limits. Low-skilled work is receptive to different development dynamics, and by no means obsolete in a modern and digitalised economy. Even if new technologies may accelerate and in some cases further automate processes, there is one aspect where they cannot substitute the human: experience.

This study, prepared for Friedrich-Ebert-Stiftung by Prof. Hartmut Hirsch-Kreinsen, shows how low-skilled work remains highly relevant. Even in a context of advancing digitalisation, its continuing significance for employers should not be underestimated, nor should it be ignored in employment policy.

Any discussion about the future of work in a context of advancing digitalisation of production must address the central question of the social, societal and economic consequences for workers. But the situation of enterprises, especially the small and medium-sized, should not be neglected either. The extent to which Industry 4.0 will change the overall situation of companies employing large proportions of low-skilled workers remains unclear.

Ultimately, politics, employers and trade unions will have to choose which path to take. Whichever this is, the modernisation goal of "good low-skilled work" must be pursued. In a debate often dominated by technical aspects, this study supplies a timely reminder that there are also traditional and less technology-intensive branches and workplaces.

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SUMMARY

The four main findings of the present study on the impact of increasing application of digital technologies and the Industry 4.0 concept on low-skilled industrial work can be summarised as follows:

(1) Low-skilled work comprises activities that demand no particular vocational qualification and can be accomplished after brief training or familiarisation processes. Typical low-skilled activities include manual operation of simple and specialised machine tools, short-cycle machine feeding, repetitive packaging tasks, monotonous monitoring tasks, and packing and commissioning in logistics. In 2013 low-skilled industrial work still represented about 23 percent of total employment in manufacturing industry in Germany.

(2) The current academic and political debate over the digitalisation of work is characterised by widely differing assumptions, with more or less explicitly diverging development perspectives for low-skilled work:
– With respect to the employment effects of digitalisation, it is uncontested that short-term redundancy effects are to be expected. It is, however, consistently assumed that simple routine tasks in particular will be increasingly automated.
– In relation to possible consequences of digitalisation for activities and skills, some assume that low-skilled work will also be affected by upskilling processes. Others foresee a skill polarisation, including the possibility that new forms of low-skilled work may emerge.
– Finally, intensifying transformation tendencies in intra- and inter-enterprise value chains are expected. These, it is suggested, will lead (above all at inter-enterprise level) to the emergence of new forms of work – crowdsourcing and crowdworking – which may also be associated with new forms of low-skilled work.

Despite their sometimes contradictory arguments, almost all relevant studies assume that a technology push is currently under way, with predictable, technologically-driven trends changing the world of work. The social repercussions cannot, however, realistically be imputed solely from the potential of new technologies. Instead a complex relationship between the implementation of technical systems and the consequences for work must be assumed, which is also influenced by many other factors. With respect to the consequences of digitalisation of work, three factors are particularly noteworthy: the limits placed on automation by the great significance of uncomputerisable experience; the pace of change in tasks and work processes; and the influence of widely differing structural conditions in enterprises.

(3) It is therefore impossible to identify a clear development trend for low-skilled work. Instead it must be assumed that several different development paths exist in a general context of advancing digitalisation of work. The current state of research allows four diverging development paths to be identified for low-skilled industrial work:
– Development path I: Automation of low-skilled work (extensive substitution);
– Development path II: Upgrading of low-skilled industrial work (upskilling);
– Development path III: Digitalised low-skilled work (emergence of new forms);
– Development path IV: Structurally conservative stabilisation of low-skilled work (existing staffing and organisational structures remain unchanged).

(4) These diverging development paths imply a fundamental conflict of goals in research and policy:
– On the one hand, modernisation and employment considerations would suggest seeking ways and means to improve the quality of low-skilled work and create “good” work.
– On the other hand, social and labour-market needs would imply stabilising low-skilled work (“bad” work) in order to preserve employment opportunities for a growing number of low-skilled workers.

In general, therefore, what is needed most of all is a broad-based research and innovation policy that expands the present technology-fixated perspective and takes into consideration traditional, less technology-intensive branches and enterprises where low-skilled work is prevalent.

1

INTRODUCTION[1]

The subject of this present study is the question of the extent to which simple, low-skilled work is affected by the increasing application of digital technologies. In the current debate it is almost uniformly assumed that new technologies will take over most simple activities (e.g. Brynjolfsson/McAfee 2014; Crouch 2015; BMAS 2015). The consequences, it is feared, will be not only significant loss of employment in this segment of the labour market, but also rising unemployment among the low-skilled, the growth of unemployed marginalised social groups and an associated widening of income inequality. Ultimately, it is suggested, this will threaten economic growth altogether, as well as social integration and stability (Collins 2013; Crouch 2015). If this scenario were to become reality, it seems obvious that the state would be faced with almost insurmountable social, labour market and economic policy challenges (see also Forschungsunion/acatech 2013: 57).

The present study presents a closer examination of these issues in relation to the development of low-skilled work in the industrial sector. One central point of reference is the recent study of the structures, dissemination and perspectives for low-skilled work in industry by Jörg Abel, Hartmut Hirsch-Kreinsen and Peter Ittermann (Abel et al. 2014), which found that this type of work still remains astonishingly important. Low-skilled work demands no particular vocational qualification and can be accomplished after brief training or familiarisation processes. It is generally tied to specific functions. Broader expertise and background knowledge are less important or completely unnecessary. Typical low-skilled activities in industry include manual operation of specialised machine tools, short-cycle machine feeding, repetitive packaging tasks, monotonous monitoring tasks, and very many warehousing and commissioning functions in logistics (Abel et al. 2014: 12).

The second major point of reference is the public and academic debate over the Industry 4.0 concept currently under way in Germany. Industry 4.0 is the idea that a fourth industrial revolution is currently beginning. Its central characteristic is the networking of the virtual computer world with the physical world of things through the application of cyber-physical systems. Such production systems should often be capable of controlling, optimising and configuring themselves largely independently and autonomously. The basis for this is the systematic collection and processing of large amounts of data about processes and especially about customer preferences (big data). This achieves a level of networking and flexibilisation of the industrial value chain unknown in earlier industrial development phases, in particular a pronounced individualisation of products and new forms of customer orientation (e.g. Forschungsunion/acatech 2013; Bauernhansel 2014). As such, it is obvious to assume that the introduction of Industry 4.0 systems will bring about deep and lasting change in work in general, and especially in low-skilled work (e.g. Botthof/Hartmann 2015; Hirsch-Kreinsen et al. 2015).

This study investigates and challenges those assumptions. First of all, the prevalence of low-skilled industrial work and development trends are reviewed (Section 2), and the state of debate on the possible consequences of digitalisation for work is summarised (Section 3). The various strands of the discussion are brought together in Section 4, where four conceivable development paths (scenarios) for low-skilled work under conditions of digitalisation are laid out on the basis of the research. Finally, in Section 5 the social, employment and innovation problems of the possible development trends in low-skilled work are discussed, together with recommendations for action.

The empirical basis of the study comprises: firstly, a long-term and ongoing observation of the Industry 4.0 discourse at all political and economic levels; secondly, ongoing literature research; thirdly, the author's own initial empirical findings on the consequences of the introduction of Industry 4.0; and fourthly, a study on low-skilled industrial work published by the author and colleagues (Abel et al. 2014).

1 The author would like to thank Jörg Abel and Peter Ittermann for constructive criticism and useful suggestions.

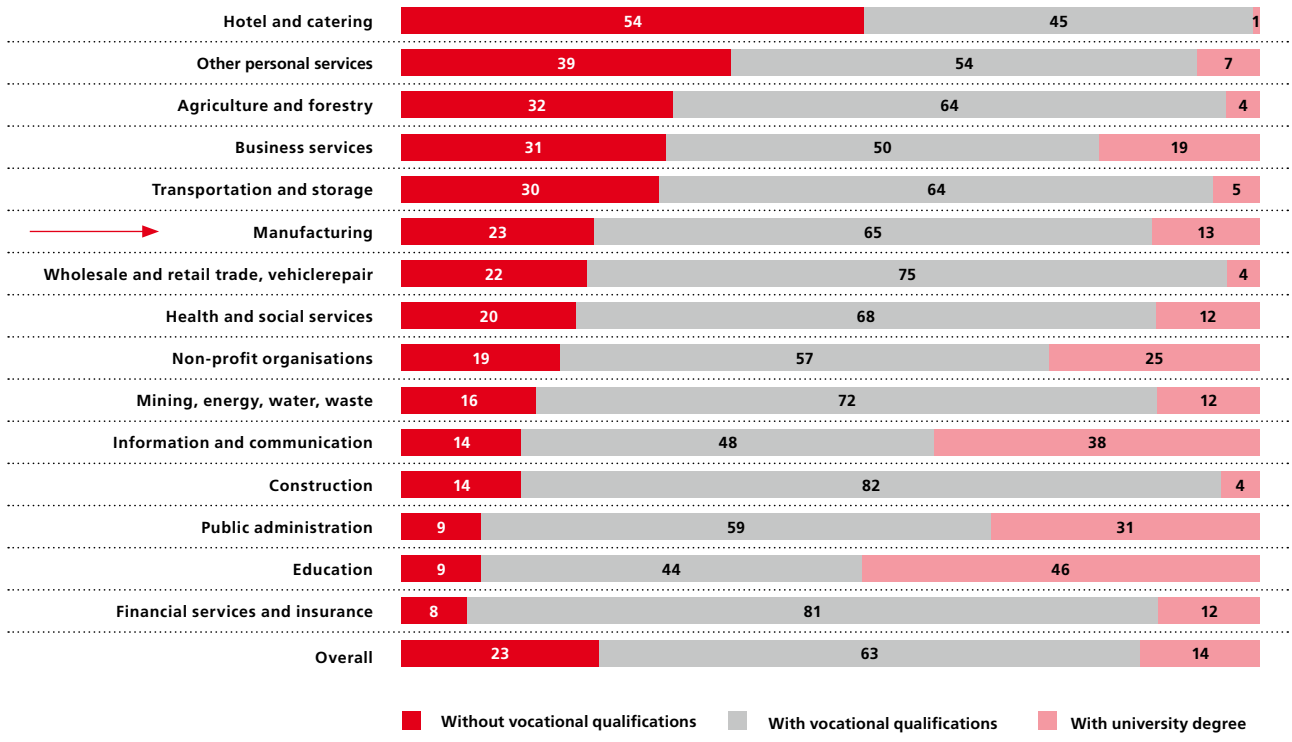
2

THE CONTEMPORARY IMPORTANCE OF LOW-SKILLED INDUSTRIAL WORK

2.1 STRUCTURE AND DISSEMINATION

According to the IAB-Betriebspanel data for 2013, about 23 percent of the labour force possess no vocational qualifications. They are found in about 48 percent of companies (Bellmann et al. 2015). While the proportion fell by 10 percentage points during the early 2000s, it has remained relatively constant over the past decade. In absolute numbers there are about 9.6 million employees without vocational qualifications. Sectorally, about 23 percent of employees in manufacturing industry were without vocational qualifications in 2013, the same figure as for the economy as a whole. This figure puts manufacturing in the top half of the sectoral list (see Fig. 1). In absolute numbers, there are about 1.2 million low-skilled workers in manufacturing.

Figure 1
Qualification structure in Germany by sector – Proportion of sectoral workforce (%)[2]



Source: Own calculations, data from IAB Betriebspanel 2013.

2 In the absence of adequate statistical granularity, certain sources also use workers' actual qualifications as an indicator of low-skilled work (see also Bellmann/Stegmaier 2007).

Examining the figures for manufacturing industry in greater detail (Abel et al. 2014), the core areas for low-skilled industrial work in 2010 were manufacture of rubber and plastic products (40.0 percent), food, beverages and tobacco (32.4 percent) and metalworking (29.1 percent) (see Fig. 2). At the heart of German industry, in sectors such as mechanical engineering, chemicals and vehicle construction, and in "installation and repair of plant and machinery", on the other hand, the proportions are below average; here skilled and highly skilled work play a larger role. Yet even closer examination reveals that low-skilled work does play a major role in individual segments of these branches. Examples include various areas of vehicle component supply, paint and soap production in the chemicals industry, and the electrical industry. In 2010 the largest numbers of low-skilled workers in industry were found in the food industry (about 260,000), in metalworking (about 230,000) and also in vehicle construction (about 175,000).

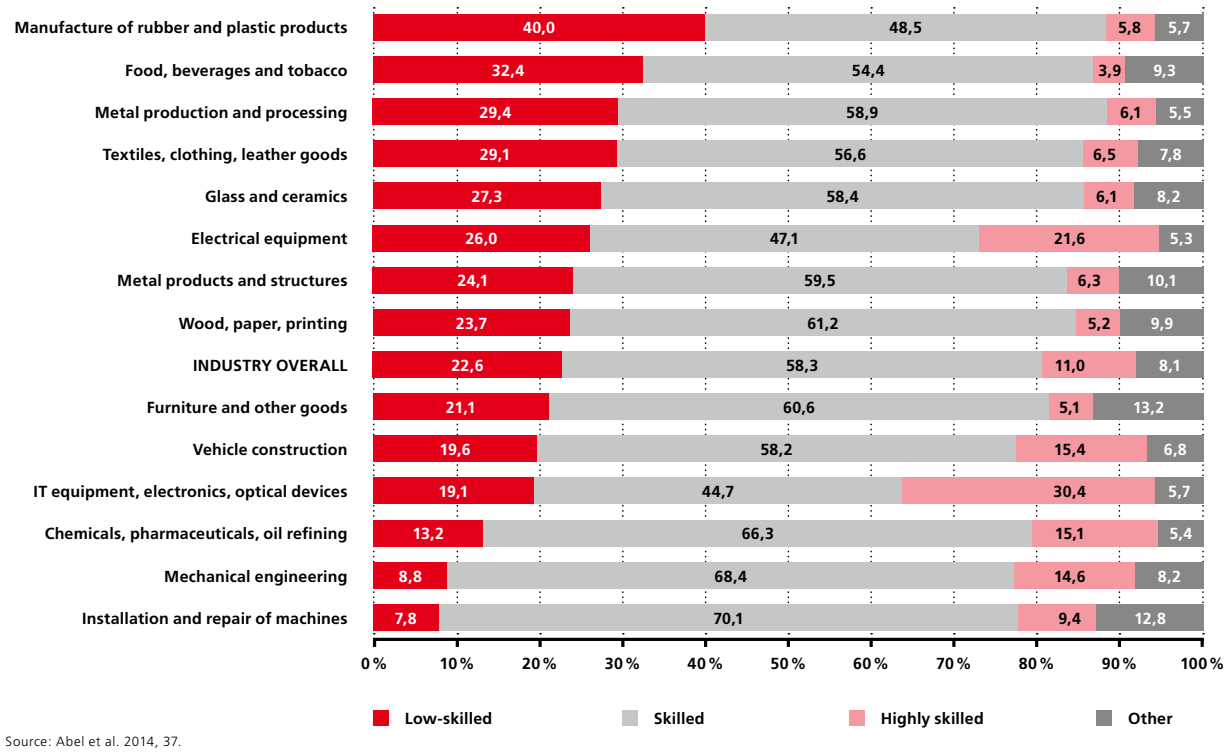
In terms of the company size the proportions of low-skilled workers are highest in medium-sized enterprises (Abel et al. 2014: 36 ff.). In enterprises with 100 to 199 employees they represent almost 26 percent of the workforce (figures for 2010); in absolute numbers the most low-skilled workers (about 460,000) are found in industrial firms with 10 to 99 employees. Overall, however, the proportion of low-skilled workers varies little among the size classes between 10 and 4,999 employees: here it lies between about 22 and 26 percent. Deviating values are found only in the very small and very large workplaces: In the smallest, with fewer than 10 employees, the mean proportion of low-skilled workers is under 20 percent. And the largest certainly have the smallest proportion of low-skilled workers: In companies with more than 5,000 employees just 13.8 percent of employees are low-skilled (2010).

2.2 CONDITIONS FOR STABILITY OF LOW-SKILLED WORK

Given the received wisdom that the secret of the German industrial model is its medium and highly skilled workforce, the high and relatively stable proportion of low-skilled workers in industry is surprising. A study by the present author and colleagues (Abel et al. 2014) found that many different factors play significant roles.

The main cause of the persistence of low-skilled work is barriers to automation. Many of the enterprises use conventional production technologies and operate under relatively tight technical and economic constraints on automation of labour processes and substitution of low-skilled jobs. Firstly, materials and processes create technical barriers to more extensive automation of production. Such barriers exist in assembly processes in the metal industry and in production and packaging processes in the food industry, for example, and lead enterprises in these sectors to choose to rely on simple manual activities. This situation is particularly prevalent in companies manufacturing special or complex products for niche segments, where short production runs, frequent product changes and product-related obstacles to investment and automation play a central role. Secondly, the technological potential of automation cannot be fully exploited where market-driven flexibility demands create excessive costs that the often medium-sized enterprises struggle to bear. Steadily expanding market-driven flexibility requirements exacerbate this cost problem of automation. At the same time, strong pressure on prices and costs requires a cost-minimising production structure realised primarily through the optimisation of existing processes and the avoidance of extensive and costly process innovations (e.g. Hirsch-Kreinsen 2008).

Figure 2
Low-skilled work by industrial sector – Proportion of sectoral workforce (%, 2010)



Source: Abel et al. 2014, 37.

Another set of causes lies in the nature of company structures. The limited technological expertise of most small and medium-sized enterprises is often completely overwhelmed by complex automation projects. Lack of capacity and know-how is frequently compounded by low levels of specialisation and professionalisation in management. For these enterprises it is in fact often a more rational decision to rely on manual low-skilled work than to pursue risky and potentially unmanageable automation projects. Moreover, the strategy of shifting simple processes to countries where labour costs are cheaper is not without its own difficulties for many small and medium-sized enterprises. Complex logistical and information issues hamper domestic customer relations and dependability of supply, while the limited resources of many small and medium-sized enterprises (SMEs) mean that their possibilities for outsourcing or moving production elsewhere are much more restricted than for large industrial companies. That relationship is without doubt behind the particular concentration of low-skilled work in SMEs (Abel et al. 2014: 194).

Finally, in some cases the established social structure of the workplace can function as a stabilising factor for existing forms of low-skilled work. Some of the evidence reported by Abel, Hirsch-Kreinsen and Ittermann (2014) suggests that under stable economic conditions managements will avoid far-reaching automation projects partly in order to avoid redundancies and the associated labour disputes. In certain cases a patriarchal attitude in the part of the owners of family businesses can be identified behind this stance.

The obvious question now is to what extent Industry 4.0 will change this overall situation in enterprises where low-skilled work is currently an important factor.

3

DIGITALISATION OF WORK – THE STATE OF RESEARCH

In the current debate, the transformation of work is mostly discussed from a general perspective, with the question of the development perspectives of low-skilled work only touched upon implicitly. At the same time, the current debate does give some important first indications of the perspectives for low-skilled work. For that reason its main strands are briefly summarised here.

3.1 JOBS: CONTESTED EMPLOYMENT EFFECTS

One currently contested academic and societal question is what employment effects will ensue from the progressive digitalisation and automation of jobs and work processes.

Many authors argue that routine – and thus low-skilled – work is subject to a high risk of automation in the medium to long term. The central reason for this, it is argued, is that the structured and routine character of these activities makes them relatively easy to algorithmise, computerise and automate. In particular, the internationally widely noted study of the US labour market by Frey and Osborne (2013) concludes that almost half of today's professions across almost all sectors could be substituted. Using Frey and Osborne's analytical concept, Bowles (2014) calculates a similarly high substitution risk for the European and German labour markets. Other authors go even further, arguing that digital automation in the German economy will endanger 59 percent of all jobs – more than 18 million – especially simple industrial tasks in the fields of machine operation, assembly and logistics (Brzeski/Burk 2015).

Other authors, while not completely rejecting these radical forecasts, would strongly relativise them. They emphasise that predictions of redundancies relate only to the automation potential of the new technologies, which cannot simply be equated with job losses. While the technologies often alter tasks, it is argued, they do not necessarily fully replace them because new tasks arise and jobs develop dynamically (e.g. Autor 2015; Pfeiffer/Suphan 2015). While Bonin et al. (2015) demonstrate that only 12 percent of jobs in Germany are endangered through digital automation, they do also predict that the probability of automation will be higher where levels of education are lower. They calculate an automation probability of 80 percent for workers with only elementary and primary education, in other words the low-skilled and low-paid (Bonin et al. 2015: 16). The authors of an IAB study (Wolter et al. 2015) argue considerably more cautiously, but in the same direction. Their general prognosis is that digitalisation certainly poses a serious threat to low-skilled workers (also Dengler/Matthes 2015).

3.2 JOBS AND SKILLS: BETWEEN UPGRADING AND POLARISATION

In view of the contradictory positions on possible redundancy effects, it is hardly surprising that widely differing answers are found to the question of the consequences of digital technologies for jobs and skills. One is the thesis that digitalisation will lead to upgrading, as consequence of the automation of simple and low-skilled activities and at the same time, a continuous enhancement of skilled activities. As such, it is a process that broadly affects all employment groups. In this line of argument, the growing availability of data and information through digitalisation leads very generally to new and previously unknown tasks and activities. (e.g. Zuboff 1988; Zammuto et al 2007; Evengelista et al. 2014; Boos et al. 2013). Standing for a long list of authors and statements, Henning Kagermann, one of the leading figures of the Industry 4.0 debate in Germany, argues that in future workers will be employed less as "machine operators" and more "in the role of the experienced expert, decision-maker and coordinator … and the individual's work becomes more diverse" (Kagermann 2014: 608). In other words, rather than low-skilled industrial work disappearing, the level of qualification rises steadily.

Many others argue that digitalisation will be associated with a strong polarisation of jobs and skills (e.g. Collins 2013; Münchner Kreis 2013; Bowles 2014; Autor 2015). The essence of the polarisation thesis is the idea of a growing gap between complex activities requiring high qualifications and simple tasks with a low skill level, with the mid-range categories

shrinking dramatically. In other words, the application of digital technologies will increasingly lead to automation and devaluation of jobs in middle skill range. Contrary to the upgrading thesis, automation will cause no dramatic decline in simple activities Instead, in fact, new simple activities with low skill requirements will emerge, where well-structured rule-based tasks are automated. It is also argued that while digitalisation will supply employees with more information and data on processes and products, IT projects will largely standardise originally complex activities through modelling and formalisation. This development, too, it is argued, will lead to the deskilling of originally demanding functions (e.g. Kuhlmann/Schumann 2015).

3.3 CROWDWORKING

A whole series of studies suggest that the new possibilities for digitalisation of work processes can also be used to bring about a deep transformation of intra- and inter-enterprise value chains. This presupposes the ability to precisely describe, differentiate and modularise originally complex work steps and thus deepen existing forms of division of labour. This permits above all a much more far-reaching differentiation and opening of production processes and the internet-co-ordinated inclusion of a wide range of external actors in the value-creation process. In the literature this process is also described as "crowdsourcing" or "crowdworking (Leimeister/Zogaj 2013; Benner 2014). Its technological basis is net-working and internet platforms that enable tasks to be put out to open tender. Empirically this development has to date been located primarily in sectors like the IT and software branch and engineering functions in the industrial sector (Leimeister/Zogaj 2013; Boes et al. 2014).

The literature spans widely differing assessments of the possible repercussions of these boundary-dissolving trends for work and skill levels. On the one hand, for example in connection with the upgrading thesis, there are arguments that emphasise a rising quality of work. On the other hand, the associated risks are discussed, for example highlighting the lack of regulation and the associated emergence of new forms of precarious employment, as well as the fact that the highly flexible and networked inter-enterprise modes of work involved here divide up and specialise originally complex tasks in a highly granular division of labour – and thus produce new forms of low-skilled work.

3.4 INTERVENING FACTORS

Despite their sometimes contradictory theses, most of the authors discussed above agree that a technology push is currently under way, with technology-driven and more or less predictable tendencies to change work. From a sociological perspective, however, it can be objected that this technology-centred approach with its insistence on often far-reaching forecasts does not go far enough. Industrial sociology has long known that the development and diffusion of new technologies is anything but a smooth and uncontradictory process, and that it is therefore almost impossible to predict social effects solely on the basis of the potential of new technologies. Instead a multitude of non-technical intervening factors must be taken into account (see esp. Lutz 1987). Reviewing the literature, the following factors emerge with respect to the consequences of digitalisation.

Firstly, limits to automation arise through problems of the inherent vulnerability of complex production technologies (e.g. Grote 2015). It transpires that coping with malfunctions requires workers – whatever their skill level – to possess accumulated experience in handling the plant in question (e.g. Böhle/Rose 1992; Bauer et al. 2006). Given its lack of explicable rules, this form of work based on tacit knowledge is fundamentally resistant to algorithm-based automation. Concretely, it comprises elements that involve a high degree of flexibility, judgement, social interaction and communication, and as mentioned accumulated experience concerning particular processes (e.g. Autor 2015). Pfeiffer and Suphan (2015) demonstrate that more than 70 percent of employees of all skill levels in Germany have to deal with such difficult or even unexplainable tasks, and that their roles are indispensable for keeping a wide range of processes running smoothly. In other words, these elements are found not only in intellectual professions involving a high degree of creativity, problem-solving ability and intuition, but also in areas of simple manual activities, where situative adaptability and flexibility, social interaction, physical dexterity and intuition are required.

Secondly, work processes themselves change dynamically under the conditions of advancing digitalisation. Where routine tasks and functions are automated at least to some extent, greater leeway for job enrichment and enlargement arises in the remaining activities (Autor 2015: 26 f.). At this point the effects of the growing availability to employees of a great diversity of data and information about ongoing processes must also be taken into account. Under certain circumstances their complexity may to new and hitherto unknown job requirements. As such, shifts in tasks and functions through digitalisation may benefit not only the already skilled and privileged groups, but can, as already mentioned, lead to an enhancement of activities and skills that also affects low-skilled work.

Thirdly, operational factors represent an often unavoidable intervening factor. First of all, the influence of company size on the dissemination of digital technologies must be underlined. There are great differences in resources and skill structures between firms of different size. The introduction of digital technologies will often permanently overstretch SMEs in particular, with their scarce resources (especially financial) (Agiplan et al. 2015: 133). It is therefore likely that this will particularly affect the large group of small and medium-sized enterprises that operate with a large element of fairly low-skilled work – whose digitalisation strategies are therefore not especially pronounced. As well as the often limited availability of technological expertise and a lack of know-how, another factor that consistently curtails the dissemination of new technologies and the associated transformation of work in this segment in particular is time pressure and competition-driven short-term thinking. As already laid out above, this factor has in the past restricted automation projects and the introduction of digital technologies in low-skilled workplaces, and must be expected to continue so doing.

4

DEVELOPMENT PATHS FOR LOW-SKILLED WORK

It is now time to bring together the research findings outlined above – in particular the very different and sometimes contradictory factors influencing the transformation of low-skilled work – to lay out various potential development paths. These different development paths for low-skilled work differ in terms of their structural conditions, level of digitalisation, and work organisation.

4.1 DEVELOPMENT PATH I: AUTOMATION OF LOW-SKILLED INDUSTRIAL WORK

The first development path is characterised by the broad introduction of digital technologies to automate work processes. The consequence is an extensive substitution of low-skilled work in production and logistics, as forecast by a large majority of labour market studies (Section 3.1). The central features of this development path are:

(1) Structural conditions: This development path comprises a broad spectrum of different types of workplace, ranging from SMEs with restricted resources and expertise through to major corporations with extensive R&D. The characteristic they all share is the manufacture of standardised products and the strategic objective of significantly increasing both the productivity and the flexibility of their production through application of the new technologies. Specific examples would include enterprises in core industrial sectors such as electrical engineering, car-making, and above all traditionally low-skilled operations in branches like metal production, food processing, furniture and above all also logistics.

These enterprises continuously strive to improve their competitive situation by increasing the flexibility of their production processes, reducing the size of production runs, and customer-specific individualisation and quality improvements. The objective – frequently raised in the Industry 4.0 debate – that the new technologies should enable a significant lowering of the automation threshold towards batch size one and a progressive individualisation of the products – refers above all to these manufacturers of standard products in a wide variety of branches (e.g. Bauernhansl 2014).

(2) Level of digitalisation: The central feature of this development path is the introduction of highly digitalised technologies, such as new intelligent lightweight robots in the immediate assembly process. The application of intelligent networked transport and logistics systems for simple packaging and commissioning tasks is also foreseeable. Another example of automation is the systematic provision of data through assistance systems and so-called augmented reality technologies, which take over simple tasks of interpreting and classifying process information (Windelband et al. 2011: 50 ff.).

(3) Work and work organisation: Some of these innovations, such as the introduction of intelligent robot systems, represent radical process innovations involving disruptive changes in work and work organisation and the far-reaching substitution of simple activities. This affects simple activities characterised by a strongly routine nature, limited complexity, low requirement of experience and sometimes high stresses. They include machine operation and standardised assembly tasks. In the logistics sector the application of smart systems can often replace the manual recording and processing of data in packaging, commissioning and operational coordination functions. In some cases these may also be ergonomically problematic activities. Experts speak of dirty, dangerous and demanding "3D activities" that can be automated using the new technologies. In the car industry the activities that tend to be substituted are those that are simple and ergonomically problematic, such as assembling, welding and bodyshop. In the metal industry, especially for example forging, the introduction of robots can replace certain extremely unpleasant jobs. According to one drastic assessment, in a few years there will be "no jobs for low-skilled workers left in industry" in Germany (Spath et al. 2013: 125).

4.2 DEVELOPMENT PATH II: UPGRADING OF LOW-SKILLED INDUSTRIAL WORK

This development path is characterised by the relatively broad introduction of digital technologies, in a form associated with an enhancement rather than erosion of

low-skilled work. The central features of this development path are:

(1) Structural conditions: This development path comprises SMEs with a high proportion of low-skilled work, with low R&D intensity, limited resources and a historically low level of application process technologies. Although technologically mature and standardised products are also produced in this context, the managements of these enterprises – often driven by growing pressure of competition and flexibility in their markets – pursue a long-term strategy of technological product improvement paired with a highly flexible marketing orientation. Examples are found among automotive suppliers seeking to move up the supply pyramid by upgrading their technologies. Other cases of this kind are found in the furniture and hardware industries, which seek to fend off growing cheap foreign competition through innovation strategies (Hirsch-Kreinsen 2008; Abel et al. 2014). This development path is also found in logistics firms hoping to realise major increases in delivery speed and flexibility by introducing intelligent systems.

(2) Level of digitalisation: Typical process technologies for this development path are, as in development path I, intelligent robot systems, smart process technologies and product components, assistance systems, and new logistics and warehousing systems. These have multiple impacts on existing low-skilled jobs: Firstly, the level of process automation increases and the work becomes functionally and temporally separated from the technological process. This decoupling can be exploited for job enrichment measures (Neumann 2015). Secondly, the scope and extent of available process data and information increases, permitting staff to gain valid and stable information and a broader overview of the process as a whole (also beyond their own job); for example, having reliable data and information can prevent unnecessary delays. Thirdly, adaptive, learning assistance systems can be used for targeted on-the-job training. By recording and processing work sequences, times and errors, such assistance systems are able to assess the operator's skill level and experience. This means the system can autonomously supply instructions, information and feedback tailored to a specific employee (Gorecky 2014; Barner et al. 2015).

(3) Work and work organisation: Under these conditions the work organisation and division of labour undergo great change. The dominant position of low-skilled work gives way to previously unknown possibilities for creating flexible and upskilled forms of work. On the shop floor, for example, demanding new activities emerge in system support and monitoring, which require a level of skill and pronounced autonomy (e.g. Ittermann/Niehaus 2015). One instructive example is the introduction of new automation technologies in the car industry. While these replace many repetitive assembly-line jobs, they also lead to the emergence of new, less routine functions such as plant operator and maintenance engineer (Neumann 2015). Another example would be assembly and commissioning tasks in the metal industry, where an order management system can take over the tasks of data gathering and troubleshooting. This permits the human roles to be expanded with new demanding responsibilities such as quality control, and it becomes possible to deploy staff flexibly at different assembly stations. Another starting point for the upgrading of low-skilled work is the targeted use of the adaptive assistance systems described above, to progressively train up hitherto low-skilled workers.

Altogether this development path describes an ongoing erosion and rejection of the low-skilled industrial work model. One instructive pointer to the trends is also found in the low-skilled work study by Abel, Hirsch-Kreinsen and Ittermann (2014): They report that this form of work is partially characterised by a continuous expansion of skills, driven by rising work requirements resulting from an IT-enabled broadening of job descriptions. These are often additional indirectly productive tasks such as process documentation, work planning and quality control (Abel et al. 2014: 139 f.). In other words, this development path represents one moment of the general dynamic of upgrading through digitalisation described above (Zuboff 1988). Given the high pressure of innovation on companies and the growing technological and economic availability of digital technologies, this development path will without doubt gain growing importance among enterprises where low-skilled work is currently still prevalent.[3]

4.3 DEVELOPMENT PATH III: DIGITALISATION OF LOW-SKILLED WORK

The theses on the digital transformation of work summarised above also suggest a third development path, the emergence of new forms of digitalised low-skilled work. The following determining factors can currently be identified:

(1) Structural conditions: This development path comprises a broad spectrum of different types of enterprise and process, ranging from digitalised intra-enterprise processes through to extensive inter-enterprise networking. The involved enterprises may be large or medium-sized, but there is a particular concentration in very small firms in a wide range of sectors. Here we find above all companies with a high proportion of low-skilled work, for example in the metal industry and the logistics branch. Altogether they use the possibilities of digitalisation and reorganisation to accelerate work processes, heavily reduce costs and above all to improve control of work processes.

(2) Level of digitalisation: The intra- and inter-enterprise work processes involved here demonstrate a high intensity of application of digital technologies. Examples include the use of cyber-physical systems and intelligent robots in formerly largely manual work processes such as assembly and packaging, and the use of information and assistance systems to optimise information flows and improve the control of work

3 Of course barriers among the low-skilled workforce, such as lack of ability or interest, must not be overlooked. Abel et al. point to the limits to upskilling, including experiments with group work in this area that failed for that reason (Abel et al. 2014: 108 ff.).

processes for example in logistics. The information and co-ordination systems that control the inter-enterprise processes of crowdsourcing and crowdworking also play a role here. These often extremely sophisticated internet platforms are as a rule developed for specific tasks and processes and control all steps from registration through tasking to remuneration. They obviously permit a very far-reaching differentiation of tasks (see Leimeister/Zogaj 2013: 46 f.).

(3) Work and work organisation: The new forms of digitalised low-skilled work emerging in this context exhibit very different patterns at the individual level. Four categories can be identified:

– Firstly, the application of new robot systems leads to a restructuring of existing low-skilled tasks and activities (e.g. Naumann 2014; Freitag et al. 2015). While automatable tasks are substituted, the remaining simple tasks can be bundled into new functions. Such partial automation permits ergonomically stressful activities to be made more humane and opens up possibilities to make manual work more age-friendly (e.g. Neumann 2015). Another example is the use of assistance systems supplying hitherto unavailable information, which can potentially optimise low-skilled activities for example in assembly processes. There are reports of semi-skilled personnel being enabled to trouble-shoot simple malfunctions using augmented reality systems. Similar trends are encountered in logistics, where systems supplying systematic work information and instructions are optimising already simple activities (Windelband et al. 2011: 66).[4] For example, data glasses can ensure that part-picking staff adhere to simple, clearly defined work sequences.

– Secondly, certain simple activities are not automatable – or only to a limited extent – because they involve responding to unpredictable situation-specific events and require a high degree of flexibility, social interaction and experience. These new forms of low-skilled work arise as "residual functions" or "automation gaps" in the context of far-reaching digital automation of work processes, for example in monitoring, feeding and data handling.

– The third aspect is the differentiation and simplification of hitherto relatively skilled activities through computerised modelling and formalisation. The application of assistance systems sometimes leaves these activities subject to very restricted freedom of action and expanded possibilities of external control (Kuhlmann/Schumann 2015: 130 f.). As described above, this process of mid-range deskilling is the central moment of the polarisation of work and skills. In industry this may affect previously skilled production tasks such as assembly, maintenance and monitoring, but also mid-level administrative and service functions. Similar trends are found in logistics, where hitherto relatively demanding functions are being strongly simplified. The consequence is that employers can now easily use cheap low-skilled personal with no need for longer on-the-job training (Windelband et al. 2011). These deskilling processes and the narrowing of scope of action are enabled by assistance systems, to the extent that these systems reduce "individual differences in user expectations" and cut down on "eventualities" in the work process (Agiplan et al. 2015: 94).

– Finally, new inter-enterprise forms of low-skilled work also arise in the context of digital crowdsourcing and crowdworking. One moment of this outsourcing of process is the simplification and fragmentation of originally complex activities, for example in R&D or marketing, in order to reduce costs and accelerate processes (Leimeister et al. 2014). This development perspective is also described as "hyperspecialization" (Malone 2011), designating new forms of differentiated and highly simplified work.

Altogether, new forms of digital value creation and work are thus emerging, which have little in common with the existing patterns of low-skilled work. On the one hand, this trend can be understood as a – socially and occupationally undesirable – new "digital Taylorism", where the digital technologies permit a level of optimisation of Taylor's principles of simplification and control of the work process that had hitherto been unattainable (The Economist 12.09.2015). On the other hand the use of digital upskilling methods also opens up new – and socially desirable – employment opportunities for less capable and learning-impaired employees. For example in manufacturing data glasses and tablets can be used to create easily learnable tasks and offer low-skilled employees a chance of gainful employment.

4.4 DEVELOPMENT PATH IV: STRUCTURALLY CONSERVATIVE STABILISATION OF LOW-SKILLED WORK

The fourth and last development path for low-skilled work is characterised by very limited application of digital technologies, and is associated with no far-reaching changes or labour market consequences. It can be described as structurally conservative, and is broadly shaped by the barriers to mechanisation and automation frequently found in the affected enterprises (see above). The central features of this development path are:

(1) Structural conditions: These are mostly SMEs with low R&D intensity and limited application of process technologies, producing technologically mature and standardised products. Structurally these are typically SMEs in traditional manufacturing industry such as metalworking and plastics, wood and furniture, or food processing. They have restricted financial resources and limited technological expertise. The decisive framework condition for this development path is relatively transparent and calculable conditions in the sales markets. These may be established competitive mass markets, or characterised by relatively strong customer relationships.

4 The *New York Times* has reported on especially restrictive effects of the use of modern information systems in Amazon's logistics processes (Kantor/Streitfeld 2015).

One such sector is found in parts of the automotive supply industry, where mass-produced standard parts must be reliably delivered just-in-time. The situation is comparable in many SMEs in the food industry, which have to be able to supply their regional home markets reliably and flexibly. We also find enterprises operating in pronounced market niches characterised by demand for variants of standard products. One typical example would be the spare parts business, which generates stable turnover over a period of many years. These requirements need to be satisfied with a high degree of structural stability in organisation and workforce.

(2) Level of digitalisation: Another central condition of this development path is that the enterprises involved succeed in achieving adequate efficiency in their relatively traditionally structured production and work processes on the basis of a low level of digitalisation. There is plainly no sustained pressure of innovation; instead ongoing rationalisation measures suffice to keep costs and competition in check and secure sales. Technological leaps and the introduction of new Industry 4.0 systems are therefore very rare. Beyond this level, there are very obviously also technical barriers (of material and process) to a significant automation of production processes. Such barriers include flexibility requirements for assembly processes in the metal industry, and for production and packaging processes in the food industry, and lead enterprises in these sectors to rely explicitly on simple – and cheap – manual activities. If at all, new digitalised systems are introduced for specific functions such as warehousing and logistics.

(3) Work and work organisation: With respect to work organisation and personnel deployment, this overall situation implies a high degree of structural conservatism and the stabilisation of low-skilled industrial work. The mode of work organisation that predominates in these cases has been characterised as classical Taylorism (Abel et al. 2014: 138 f.). This structural conservatism is often accompanied by strong scepticism among decisive management representatives towards the promises of the Industry 4.0 concept. Under the described conditions the established work organisation and division of labour will survive and the dominance of low-skilled work in production will be largely preserved with a stable development perspective.

4.5 PERSPECTIVES

Closer examination of the development perspectives associated with the digitalisation of production reveals that – despite all the forecasts of its demise – low-skilled industrial work is certainly not going to disappear, not even in the longer term. Instead it must be assumed that it is subject to a pronounced development dynamic, that its appearance will become more differentiated, and that further fragmentation is to be expected. On the basis of the available research, four – in certain respects very different – development paths for low-skilled industrial work can be outlined (for summary see Figure 3).

The overall development is characterised by unsimultaneity:

- On the one hand, certain segments of low-skilled industrial work are eroding as a result of automation and upskilling trends.
- On the other, low-skilled industrial work continues to represent a relevant employment segment in industry. The principal reasons for this are the emergence of new forms of digitalised low-skilled work and the inertia of existing work structures.

Figure 3
Development paths for low-skilled industrial work

Dimensions	Development path I: Automation of low-skilled industrial work	Development path II: Upgrading of low-skilled industrial work	Development path III: Digitalisation of low-skilled work	Development path IV: Stabilisation of low-skilled work
Structural conditions	Different enterprise types with high technology intensity and corresponding resources, strong pressure of competition, individualisation of products.	SMEs with rising technology intensity, use of external technology partners, growing pressure of competition and flexibility, product improvement.	Different types of enterprise and prices, pressure of cost and innovation	Less technology-intensive SMEs with limited resources and expertise, stable market conditions
Level of digitalisation	Digitally automated processes, disruptive innovations	Increasingly digitalised processes, especially assistance systems	Pronounced, cyber-physical systems, assistance systems, internet platforms	Efficient traditional and structurally conservative optimised processes
Work and work organisation	Far-reaching substitution of low-skilled work	Substitution plus expansion and enhancement of activities New freedom of action in work	New forms of low-skilled work Unautomatable forms of low-skilled work Devaluation of complex activities, but new employment opportunities for the low-skilled	Structural conservatism, preservation of classical Taylorised forms of work

Source: Author.

As well as unsimultaneity between different branches and types of enterprise, such a situation may also be encountered within individual enterprises, where these possess different production segments with different levels of technology, different degrees of standardisation and different flexibilisation requirements. It is in fact not uncommon to find areas of traditional low-tech work alongside completely restructured high-tech segments within one and the same company (Hirsch-Kreinsen 2008). There can be no doubt that advancing digitalisation will reduce the overall proportion of low-skilled industrial work.[5] But there is good reason to expect – despite the many forecasts to the contrary – that a significant segment will remain.

5 One indication of this is found in data published in early 2016 by the employers' organisation in the state of North Rhine-Westphalia, showing that low-skilled jobs as a proportion of all industrial jobs in North Rhine-Westphalia had fallen from 24 to 20 percent. Advancing automation was named as one of the reasons (FAZ 6.02.2016).

5

RESEARCH AND POLICY CHALLENGES

Examining the challenges for research, and in particular the political challenges that flow from the research findings, a fundamental conflict of goals becomes apparent.

– On the one hand, modernisation and employment considerations would suggest seeking ways and means to improve the quality of low-skilled work and create "good" work.

– On the other hand, social and labour-market needs would imply stabilising low-skilled work ("bad" work) in order to preserve employment opportunities for a growing number of low-skilled workers.

The current dominant academic and political focus on expertise-based modernisation of industry through digitalisation and Industry 4.0, however, evades this conflict of goals and addresses exclusively the perspectives of enhancing low-skilled industrial work and modernising the affected enterprises and branches. This is the case even though Forschungsunion and acatech's 2013 implementation recommendations for the Industry 4.0 project already mention the problematic social repercussions of such a one-sided focus: "The reduction in low-skilled manual work can be expected to continue, threatening the exclusion of at least parts of the workforce (especially the semi-skilled). This would be acceptable neither to the employees, nor with respect to the political objective of social integration – and highly dysfunctional for the successful realisation of Industry 4.0" (Forschungsunion and acatech 2013, 57).

The following three central challenges for employment research and policy – further differentiated at the levels of union policy and state policy – would address the aforementioned conflict of goals and at the same time contribute to both upgrading and stabilising low-skilled work.

(1) Employment research: Under the current state of research, the outlined development paths of industrial low-skilled work are obviously hypothetical in nature. They require empirical validation above all with respect to their quantitative dissemination and their organisational and skill structures. Naturally these questions need to be placed in the context of the diverse still open research questions concerning the social consequences of Industry 4.0. Three complexes are especially relevant in the ongoing debate:

– Firstly, there are fundamental questions concerning the scope, levels and dimensions of change in skills, responsibilities, activities and work organisation. The questions here concern above all the necessary qualification and training requirements and the hitherto largely ignored questions concerning the control potential of technological systems and the consequences of temporal and spatial flexibilisation.

– Secondly, there is the question of what options exist for shaping industrial work, especially for low-skilled work, and what the possibilities are for avoiding unacceptable work situations. Here we must also ask, for example, to what extent the existing criteria for humane working conditions need to be updated.

– Thirdly, especially in connection with enterprises with a high proportion of low-skilled workers, we must examine the chances for employees and their representatives to exert influence – under the given statutory framework – on the introduction and configuration of the new technological systems.

– Fourthly, broader structural shifts must be addressed. Research should no longer be restricted solely to industrial processes, but should systematically include the interrelationships with manufacturing-related services and the general transformation of industrial value chains.

These and other questions define the outlines of a sociological research programme tackling the transformation of industrial work, especially low-skilled work, in the context of the introduction of Industry 4.0. Such a research programme can comprise both basic research and application oriented re-

search. In any case however the novelty and complexity of the topic suggests an interdisciplinary approach in cooperation between work-related social and technological disciplines.

(2) Labour policy on tariff and enterprise levels: The core areas of low-skilled industrial work have to date been a "grey zone of workplace interest regulation" (Ittermann et al. 2013), in the sense that workers' representation is often weak or non-existent in the typical small and medium-sized enterprises in this employment segment. Trade union organisation is also weak and this type of workplace with its low-skilled employees is not necessarily a priority of trade union activity. In view of the advancing digitalisation of industry, this situation faces the actors of co-determination above all with the challenges of generally improving the workplace representation situation, or at least enforcing minimum standards of workplace co-determination on the broadest possible footing.

Above and beyond this, workplace co-determination has a vital role play in enterprises where new technologies are introduced and upskilling processes can be initiated. All available evidence points to the inclusion of works councils and workforce participation being a central condition for success (e.g. Forschungsunion and acatech 2013). In many cases, however, this requires first of all systematic qualification and professionalisation of works council members to equip them for the new challenges of Industry 4.0. Especially workers' representatives in the low-skilled industrial segment need to be included much more systematically in union-negotiated and enterprise-level qualification and training arrangements. It is also foreseeable, in the low-skilled segment too, that new challenges will arise at collective bargaining and enterprise levels concerning the regulation and reform of increasingly flexibilised working conditions.

Finally it must be emphasised that notwithstanding the debate over the perspectives of "good" work, the social and labour market necessity of stabilising low-skilled work and thus often preserving "bad" work must be taken into account (also at the employment policy level). In particular the normative discourse on "good work" needs to be critically expanded. The question is, whether one can speak of forms of "good low-skilled work" and what the decisive criteria for that might be.

(3) State policy: State action is needed first of all in connection with social and labour market policy. With respect to the stabilisation of low-skilled work (development paths III and IV) the spectrum of instruments for integrating the low-skilled into the labour market, promoting their recruitment and employment, and securing their status through state transfer payments needs to be preserved and improved. Beyond this, social policy must also respond to the growing longer-term role of temporary and flexible employment and differentiated forms of inter-enterprise crowdworking. There is increasing discussion (e.g. BMAS 2015) about how precarity can be avoided and social security of employees improved. Above all this general debate must address the new low-skilled crowdworking activities outlined above.

Secondly, education policy is confronted with new challenges. The Industry 4.0 debate is characterised by demands to develop skills and qualifications with a focus on the dimensions of both initial and further training (e.g. Forschungsunion/acatech 2013; BMAS 2014). There is no doubt that the recommendations from this debate are especially relevant for those employees who find themselves – as outlined in development path II – confronted with growing work and skill requirements. Starting points exist for example in measures instituted by the German Federal Employment Agency, such as its programme for additional training for the low-skilled and older workers and the initiative for supporting structural change, but need to be developed and updated in view of the rapid pace of technological change. It must, however, be remembered that this often involves workers without learning experience who have previously had little involvement with vocational training. Such training measures are often also likely to represent uncharted waters for the small and medium-sized enterprises involved here. Therefore, ongoing skill development measures – as one of the central preconditions for the diffusion of Industry 4.0 technologies – need to be orientated in the broadest sense on this target group.

These development measures should not be directed one-sidedly towards the desirable process of upgrading of activities and skills. Instead, attention should also be directed towards the stable and structurally conservative employment segment (development path IV) and the newly emerging digitalised low-skilled jobs (development path III). Here again the question arises of how low-skilled workers (whose numbers are likely to increase rather than decrease in coming years) can be trained and qualified for permanent employment in these areas.

Thirdly, there is need for the various levels state technology and innovation policy to address the development conditions of low-skilled industrial work. One decisive condition for the design leeways available in the workplace is the configuration of the technical systems (e.g. Grote 2015; Windelband 2015). Although there appears to be consensus in the Industry 4.0 debate that the development of technical systems is driven by an ideal of "human-centred automation" (e.g. Barner et al. 2015), it remains largely unclear how that model needs to be concretised for a desirable development of low-skilled industrial work. This affects, on the one hand, the question of how the desired continuous upgrading of low-skilled work can be consistently promoted in the ongoing work process, for example through correspondingly configured information and assistance systems. It also, on the other hand, affects the question of the extent to which specially adapted IT systems would also be useful in the segment of structurally conservative low-skilled employment and what consequences this could have for the activities and skills found there. In these cases it would be important to avoid setting in motion an upskilling process that in the longer term blocks employment opportunities for the low-skilled.

Finally, it must be emphasised that these challenges demand a broad-based research and innovation policy (see also Buhr 2015). Broad-based in the sense that it is tailored in its entirety to the widest range of industrial and interconnected social conditions, rather than pursuing a solely technology-led perspective. The current high-tech and

Industry 4.0 policy is without question broad-based in attempting to integrate the social and skill aspects and consequences of technological innovation into its approach. However, it focuses above all on large technology-intensive companies and the highly innovative medium-sized "hidden giants". To date it has ignored the fact that Germany's industrial structure is considerably broader and still includes traditional branches and sectors that are not research-intensive. To date these areas have been given at best marginal attention in the context of the Industry 4.0 debate, if at all. In particular the stabile segment of low-skilled industrial work described above is not addressed. Given that this segment will continue to remain indispensable – above all for employment and social policy reasons – the Industry 4.0 debate and the application concepts developed within it must systematically address its specific conditions. Here it should be assumed that traditional and non-research-intensive enterprises and sectors with low-skilled industrial work do still possess long-term development perspectives in a "high-tech" environment.

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