The Challenges of Industry 4.0 for Small and Medium-sized Enterprises

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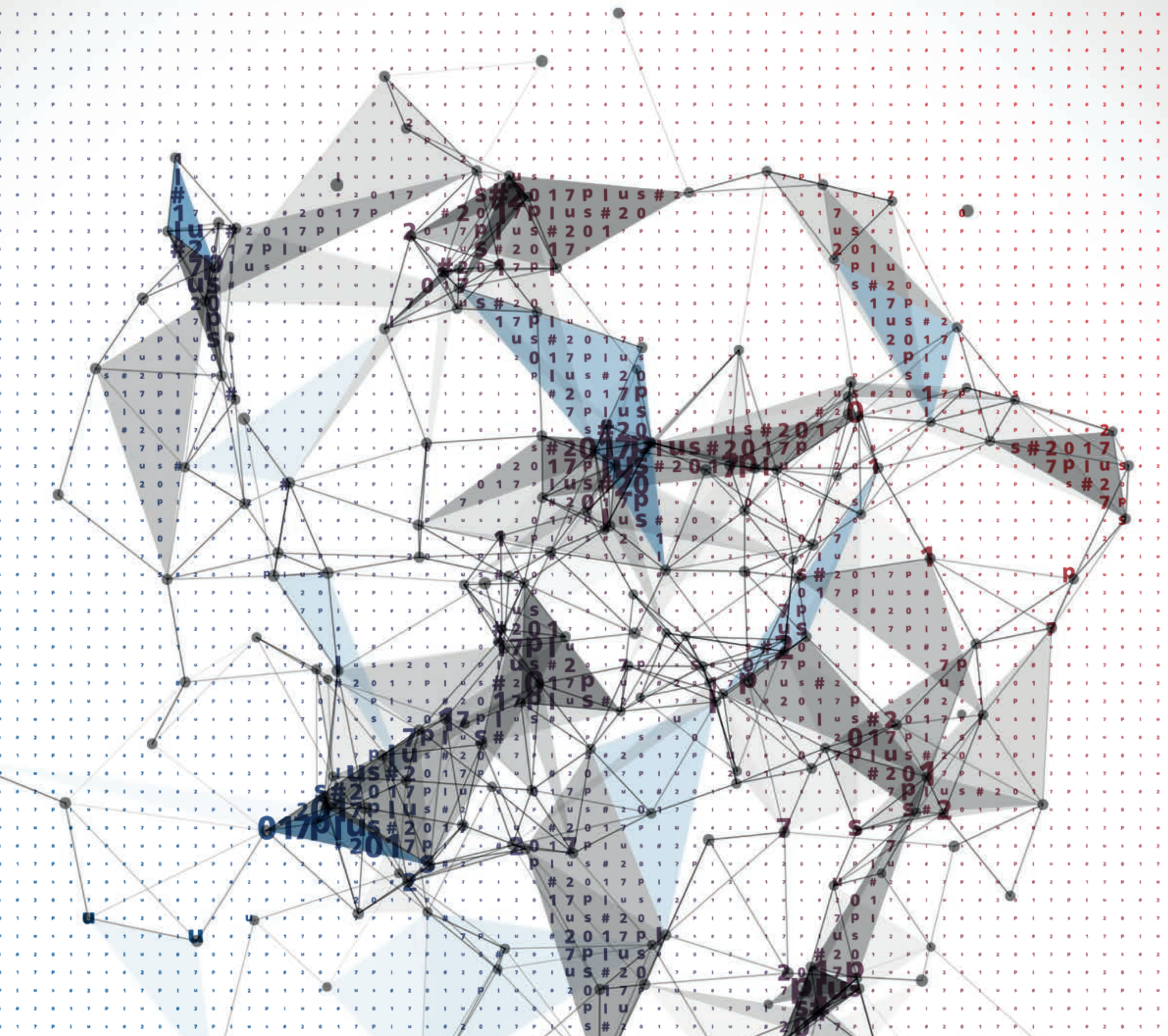

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PRELIMINARY NOTE

Industry 4.0 is a term for the digital revolution in industrial production emerging from the comprehensive networking and computerisation of all areas of production. Equipment, machinery, materials and end products apprehend environmental conditions and processing status via sensors, communicate with one another via embedded software and thus optimise the production process in an unprecedented manner. This enables companies not only to organise their production process more efficiently, but also, for example, to manufacture customised products within the framework of and at the same cost as automated manufacturing. Entirely new business models can also emerge in this way, for example, based on the evaluation and utilisation of masses of incoming data, for instance, from the provision of optimised maintenance services.

The changes arising from the digital revolution in the production and value creation process are radical and pose a real challenge to enterprises. In order not to be left behind companies need to develop strategies in good time to exploit the new possibilities of digitalisation, to improve established processes and develop new business models. Those who persistently lag behind run the risk of premature demise. For Germany as a business location and the safeguarding of prosperity there it is thus crucial that companies get a grip on these transformational dynamics early on and adapt their enterprise strategy accordingly. However, a good political, legal and infrastructural framework is also required to enable companies to rise to the challenge of Industry 4.0.

While many large companies are already attempting to anticipate the potential and risks of digitalisation for their respective business models and have introduced innovation processes, small and medium-sized enterprises appear to be making heavy weather of it. The reasons for this are manifold; they are partly internal, but they also arise – and this should give policymakers pause for thought – from the environment. Given the major importance of small and medium-sized enterprises (the so-called Mittelstand) for the German economy – around 95 per cent of all companies in Germany are considered part of the Mittelstand and there are around 690,000 small and medium-sized enterprises (SMEs) in production alone – this finding is worrying, to say the least. The aim for policymakers should thus be to optimise the framework conditions and support structures so that as many manufacturing SMEs as possible meet the challenge of Industry 4.0 and take advantage of the opportunities of the fourth industrial revolution.

The present report is a review of the literature that shows the state of implementation of Industry 4.0; presents typical obstacles and challenges for the Mittelstand; demonstrates the importance of involving employees to improve the success of innovation processes in the company; and derives political recommendations to improve the overall framework.

We hope it makes stimulating reading.

DR. ROBERT PHILIPPS
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consumer policy discussion group
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SUMMARY

Industry 4.0 is a term for the so-called »fourth industrial revolution« and in essence means the technological integration of cyber-physical systems (CPS) in the production process. CPS enables (internet-based) networking with all participants in the value creation process.

The Mittelstand has not yet discovered Big Data and the Cloud for itself

Despite the enormous economic potential of Industry 4.0 SMEs in industry remain relatively cautious about it. For example, around 5 per cent of SMEs are thoroughly networked and a third of them are taking the first steps in that direction or at least have concrete plans to do so. The spread of Industry 4.0 depends on company size. The level of dissemination among large companies is higher and they are more likely to deploy the relevant Industry 4.0 technologies than small and medium-sized enterprises. The leading sectors with regard to Industry 4.0 include manufacturers of rubber and plastics and of machinery and plant engineering. With regard to individual Industry 4.0 processes and technologies, however, it appears that across the board, regardless of company size and branch, little use is made of the evaluation of large data streams to optimise processes or for downstream services. Accordingly, little use is made also of higher level cloud services that are useful for that purpose, in contrast to SMEs elsewhere in Europe.

Small and medium-sized companies often lack a comprehensive strategy

The integration of the data generated in the value creation process requires the networking of various IT systems both within and beyond the company. In this way functional areas such as procurement, production and sales can exchange their data in real time. It is not easy for small and medium-sized enterprises, due to lack of resources, to assess the technological maturity of the relevant solutions and their business uses. Management lacks a methodical approach to implementation. Thus four out of ten SMEs do not have a comprehensive Industry 4.0 strategy compared with two out of ten among large companies.

Serious security concerns hinder implementation

A lack of standards and norms with regard to interface technologies is another reason why investments in the integration of IT systems are either not carried out or delayed. Small and medium-sized enterprises worry not only about opting for the wrong standard, but also about data security. At present, SMEs are adapting to the standard of the large company they supply. The lack of general standards thus makes it difficult for SMEs to join value creation networks with different standards and norms, thereby constraining their room to manoeuvre.

Changes in the world of work, yes; job losses, no

Worries that automation is leading to major job losses in Germany are largely unfounded. Industry 4.0 can unfold its potential only by means of the practical knowledge, acumen and adaptability of employees. While it's true that simple repetitive work is increasingly being replaced new jobs are emerging elsewhere due to new business models. The challenge for small and medium-sized enterprises is to create flexible organisational structures and to boost their employees' interdisciplinary thinking. Employees' existing qualifications and experience thus have to be deployed in the introduction of Industry 4.0 and enabled to reflect on production processes and to bring about continuous improvements. Industry 4.0 requires a reallocation of tasks and new responsibilities that need to be underpinned by appropriate further training measures, as well as consensus-oriented concepts of data protection and mobile work, which have to be developed with the participation of workplace codetermination bodies.

Framework conditions offer a good starting position

Germany's Mittelstand is innovative and internationally competitive. The country also has substantial technical knowhow with regard to numerous Industry 4.0 technologies and a well educated and trained workforce. The framework conditions have improved in the past year as a result of state promotion of Industry 4.0 technologies and cross-cutting issues, as well as support measures for implementation and awareness-raising. However, there is a need for action in expanding the broadband infrastructure on the basis of fibre optic cables and technologies that provide consistently high transfer rates. If it also proves possible to establish uniform, secure and open standards for data transfer the Mittelstand will have every chance of overcoming the challenges accompanying Industry 4.0.

1

INTRODUCTION

Industry 4.0 (Industrie 4.0) is a synonym for the fourth industrial revolution. The term originated with a future-oriented project that was part of the German government's high-tech strategy. It has now become widely established in the public debate in Germany and boils down to the technical integration of cyber-physical systems (CPS) in production and logistics, as well as the application of the so-called »internet of things« and the »internet of services« in industrial processes, including the consequences of all that for value creation, business models, downstream services and work organisation (Forschungsunion/Acatech 2013: 18). Considerable economic potential is attributed to CPS technology in industry. This potential is realised by means of the (internet-based) networking of all elements of the value creation process in real time, enabled by CPS technology.

Basically, the use of networking increases with the number of network partners. Because around 95 per cent of all companies in Germany are part of the Mittelstand and around 690,000 small and medium-sized enterprises (SMEs) are involved in production alone, Industry 4.0 can really only pay dividends with production SMEs. At present, however, only 5 per cent of Mittelstand manufacturing companies have networked their machinery, plants and systems across the board. Clearly there are reasons deterring small and medium-sized enterprises from implementing Industry 4.0.

The present report shall thus focus on the main challenges for Mittelstand companies with regard to Industry 4.0 and how the relevant framework needs to be tailored to support them in meeting these challenges. First, however, we need to clarify how widespread Industry 4.0 is and what its economic potential is.

The report directs its attention to industry because it generates more than 25 per cent of value creation in Germany. It is thus not only of major significance for the national economy, but the potential of Industry 4.0 technologies is most evident in it. Production in Germany faces the challenge of, on one hand, retaining a leading position as supplier of machinery and equipment (lead supplier) by means of the integration of Industry 4.0 technologies and, on the other hand, improving the competitiveness of German industry through the integration of users (lead market) (BMWi 2015: 3). The application of CPS technologies in intermediate and end products gives rise subsequently to cross-sectoral potentials for additional business support services (business-to-business) and for household services (business-to-consumer).

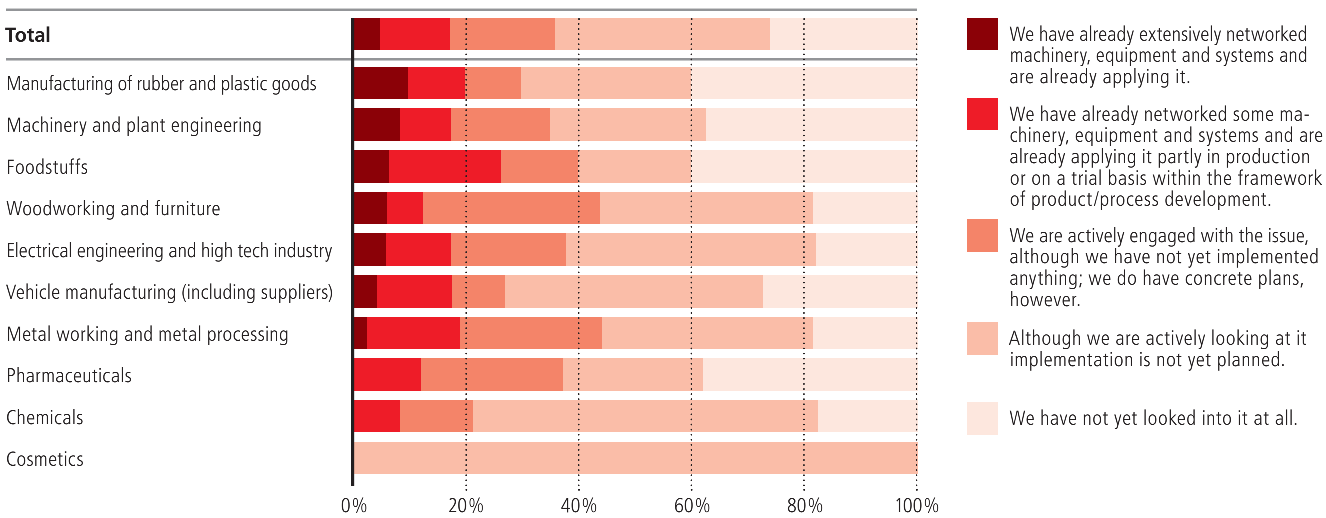
2

STATUS OF INDUSTRY 4.0 IN SMALL AND MEDIUM-SIZED ENTERPRISES

In manufacturing industry, which represents the largest part of production, around 10 per cent of companies are currently operating intensively with Industry 4.0. In machinery and plant engineering, as suppliers of Industry 4.0, the proportion is double that. At present 5.6 per cent of machinery and plant engineering companies are in a state of advanced implementation, just under 18 per cent are engaged with Industry 4.0 concepts and implementing the first measures to put them into practice (IW Consult/FIR 2015: 8). A fifth of machinery and plant engineering companies, as well as a quarter of companies in manufacturing industry as a whole indicate that Industry 4.0 is unknown or unimportant to them (IW Consult/FIR 2015: 26). There is a significant relationship between company size and implementation of Industry 4.0. Large companies are substantially more advanced in the integration of their production plants in higher-level IT systems than medium-sized companies and the latter are much more advanced than small companies (IW Consult/FIR 2015: 26).

A comparable survey solely among small and medium-sized enterprises in manufacturing industry – both providers and users of Industry 4.0 – comes to similar conclusions. Overall, the proportion of extensively networked small and medium-sized enterprises, at just under 5.5 per cent, is similarly high (see Figure 1). Differentiation by branch shows that the production of rubber and plastic products, with a proportion of 10 per cent, comes ahead of machinery and plant engineering (around 8 per cent), followed by foodstuffs (around 6.5 per cent), woodworking/furniture (around 6 per cent), electrical engineering and high tech industry (around 5.5 per cent) and vehicle manufacturing (including suppliers) at 4 per cent. A further 13 per cent of small and medium-sized enterprises in manufacturing industry have already networked some machinery, plants and systems; 17.5 per cent are engaged with it and have developed their first concrete implementation plans; just under 40 per cent are looking at it; and around 25 per cent of SMEs have still not looked into it at all (Techconsult 2015: 19).

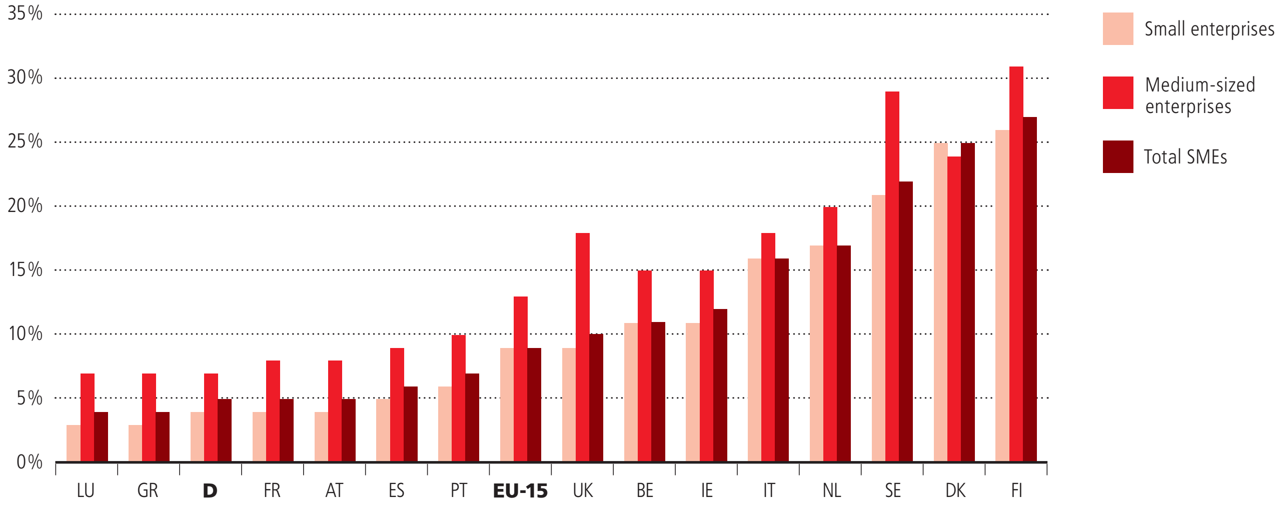
Figure 1
Level of implementation of extensive networking (estimate 2015)



Source: Techconsult (2015: 19)

Studies also have comparable findings when it comes to their evaluation of the extent to which individual Industry 4.0 processes and technologies are already in use. Both large companies and SMEs leave a lot to be desired when it comes to the use of smart services, such as the evaluation of big data that accrue in the production process or through networked production processes. Because SMEs are relatively well positioned with regard to the linking of machines and IT systems the deficiencies concerning data evaluation are not necessarily the result of a basic lack of data (Techconsult: 2015: 80; IW Consult/FIR 2015: 28). However, the complete integration of IT, which also enables external information exchange, is rare. For that purpose cloud services would be useful. In future communication between different systems will be organised via higher cloud services, such as virtual platforms (cloud platform as a service) and software (cloud software as a service). Currently, a mere 5 per cent of all SMEs in Germany use higher cloud computing services of this kind (Schröder 2015: 9). The average level of diffusion in the EU15 is twice as high as in Germany (see Figure 2). In Finland and Denmark, as many as a quarter of SMEs make use of higher grade IT services from the cloud (Schröder 2015: 10).

Figure 2
Utilisation of fee-based higher cloud computing services (2014)



Source: Schröder 2015: 10, (based on Eurostat data).

3

ECONOMIC POTENTIAL OF INDUSTRY 4.0

3.1 POSITIVE MACROECONOMIC EFFECTS EXPECTED

The economic potential of Industry 4.0 is regarded positively across the board (see Berger 2014; BITKOM/IAO 2014; PwC 2014). Because there is necessarily some degree of uncertainty in any prognoses, which in any case rest on different assumptions, the predicted positive macroeconomic effects likely to accompany networked production along the value chain vary considerably. Thus by 2020 additional annual sales of between 20 and 30 billion euros are expected (Wischmann et al. 2015: 19). It should be noted, however, that the evaluation of such effects is difficult, for a number of reasons. Not only is Industry 4.0 not defined uniformly and thus is not clear-cut, but we are also not talking about a single technological innovation, but rather a combination of various technologies that can only unleash their full potential together. Some of these technologies are in an advanced state of development, but it will be some time before they are ready for the market. The various levels of technological maturity make it difficult to predict the speed with which the new technological applications will come into commercial use and thus also when and to what extent positive network effects will be reaped. Network effects arise from networking beyond the enterprise and increase with each additional network partner (Wischmann et al. 2015: 39).

Even though the macroeconomic potential is fairly difficult to quantify we can certainly assume that internet-based applications will transform production in the medium to long term. The widespread deployment of networked production facilities in Mittelstand production industry will be of the utmost importance for the future competitiveness of the German economy.

3.2 MORE FLEXIBLE PRODUCTION WITH FALLING PRODUCTION COSTS

From a technological standpoint CPS forms the core of Industry 4.0. The basic technology of CPS comprises so-called embedded systems. Embedded systems as the key component of CPS are basically mini-computers, which are capable of measuring physical states, such as temperature or pressure, through sensors. A processor processes this information and computes appropriate measures in accordance with a predefined program (Fraunhofer IPA 2014: 11). Such a measure could, for example, trigger physical actions by so-called »actors« if a predefined environmental temperature is reached. This linking of hardware and software components is aimed at governing, regulating or monitoring a previously defined system (Fraunhofer IPA 2014: 12).

In recent years it has proved possible to miniaturise embedded systems and put them on a chip. Their performance has improved dramatically as production costs have fallen. The most significant innovation, however, is that embedded systems equipped with an IP address and modern communication interfaces, integrated in the internet, have become part of CPS. CPS functions wirelessly and can be built in to almost any object. Often CPS obtains its operating power from the environment, for example, from light or gentle vibrations that are converted into energy. CPS technology can be embedded in blanks and intermediate or end products, which are now »smart« in the sense that, for example, they know where and in what state of completion they are. The intermediate product or built-in CPS has information on what machine it will be processed by next, as long as the machine is able to communicate wirelessly. Real production processes can now be mapped virtually. As a result, production can be decentralised in real time and not – as has hitherto been the case – organised centrally (Fraunhofer IPA 2014: 12).

Parts of production can thus communicate not only with one another and with manufacturing plants, but also – via human–machine interfaces – humans can intervene directly in this communication process (Fraunhofer IPA 2014: 14). Processes can be visualised, for example, in the form of a graphic presentation of production data. The emerging machine-machine and human-machine networks are able to optimise themselves automatically and, in interaction with people, solve problems themselves (Bauernhansl et al. 2014: 16). This is what is meant by the »smart factory«.

Hand in hand with the deployment of CPS goes the expectation of higher productivity increases because in this way stocks can be reduced, personnel planning improved, logistics optimised and complexity and maintenance costs lowered. Furthermore, an increase in product quality can be expected, alongside more flexible manufacturing options. Experts even predict that maximum flexibilisation will be achieved with batch size one; that means that a customised product can be made for customers at the same price as a serial product today, providing a considerable boost to customer satisfaction.

The potential savings for different areas of production, according to a calculation by Bauernhansl (2014: 31) lie between 10 and 70 per cent (see Table 1). Complexity costs could be cut the most.

Table 1
Evaluation of potential benefits

Type of cost	Total value
Inventory costs	–30 % to –40 %
Manufacturing costs	–10 % to –20 %
Logistical costs	–10 % to –20 %
Complexity costs	–60 % to –70 %
Quality costs	–10 % to –20 %
Maintenance costs	–20 % to –30 %

Source: Condensed presentation after Bauernhansl (2014: 31)

3.3 VALUE CREATION NETWORKS AND NEW BUSINESS MODELS

Making full use of the potential of CPS requires the additional deployment of complementary IT technologies. Thus software applications are needed to structure and evaluate the large quantities of data generated by CPS in order to govern, regulate or monitor target-oriented processes. Only an enormous increase in hardware processor and memory performance, as well as fast internet connections can make this possible in real time. This also makes downstream business models possible: for example, embedded CPS enables a turbine manufacturer to provide customers with remote maintenance and, at the end of the product's life cycle, recycling as additional services.

The sophisticated hardware and software needed to cope with large real-time data streams would not have to be maintained by companies themselves. Thanks to fast internet connections they could also utilise the services of cloud providers. Providers of cloud computing services make IT infrastructure available to their customers online. Companies' capital costs are reduced as they do not need their own server or software. And because billing is in accordance with actual use efficiency losses due to underutilisation of a company's own IT infrastructure are avoided. Last but not least, location is no obstacle to use of such services.

The use of CPS could in future also underpin the value creation process beyond the company. Companies in such a case would hook up with value creation networks. Via virtual platforms in the cloud companies could access production according to need in order to coordinate production stages in real time. Also in this context one could imagine additional services; for example, free machine capacity could be offered for rental by companies with capacity bottlenecks.

Germany is in a position to benefit enormously from the potential of Industry 4.0. For example, not only is the share of industry in the German economy relatively high, but the country is also a world leader in machine-building and plant engineering, as well as automation technology. Accordingly, user and provider potential is high (Deutsche Bank Research 2014: 10). Current developments indicate that the biggest impulse for the dissemination of Industry 4.0 will come from large companies. They have the resources to switch to networked production and the economic benefits for them are already high at the current stage of development. Because – as already mentioned – the utility of Industry 4.0 increases with every new network partner large companies will encourage their mainly SME suppliers to adapt their production technology step by step in order to make their own production increasingly networked. In order that such development makes it as far as the smaller SME suppliers in cascade fashion, however, the latter will have to meet a series of challenges.

4

OBSTACLES FOR THE TECHNOLOGICAL IMPLEMENTATION OF INDUSTRY 4.0

The degree to which Industry 4.0 applications are disseminated depends on size of enterprise (IW Consult/FIR 2015: 26; Experton Group 2014: 31; GfK Enigma/DZ Bank 2014: 11). Large companies produce in high volumes, relatively capital intensively. Constant optimisation of highly automated production is a permanent element of process management. In SMEs the proportion of manual and hybrid activities is much higher. They produce rather for niche markets and often have a high degree of specialisation. In comparison with SMEs, large companies will realise much higher efficiency gains from the use of Industry 4.0 technologies.

As the range of technological options increases small and medium-sized industrial enterprises will have to take advantage of developments towards networked production. Otherwise their international competitiveness could be threatened. The biggest challenges that small and medium-sized enterprises have to meet in this context are the development of an appropriate strategy, a cost–benefit analysis of the relevant technologies and lack of data security and uniform standards.

4.1 LACK OF A DIGITAL STRATEGY ALONGSIDE RESOURCE SCARCITY

The availability of consistent data is an important condition on the way to Industry 4.0. Information must be consistently available both vertically and horizontally along the value creation chain. One talks in this context of, on one hand, vertical integration, in the sense of the integration of various IT systems into a seamless solution. Compatibility will thus be achieved between the various IT applications, processes and data of the company's functional areas, such as procurement, production and sales. Horizontal integration, on the other hand, is the integration of various process stages between which there are flows of materials, energy and information (Forstner/Dümmler 2014: 199). One example of this is an Enterprise Resource Planning (ERP) system, which takes care of material-related, scheduling and capacity planning of order processing and is linked to a Manufacturing Enterprise System (MES) in the company's software architecture. This takes care of short-term, detailed planning and control of individual production orders. Based on such coordination between the various levels of the hierarchy by means of complementary IT solutions efficiency is boosted and throughput times are shortened (Mussbach-Winter/Schatz 2012).

The particular set of IT systems, machinery and processes at a given small or medium-sized enterprise tends to have been acquired over time; machines and equipment come from various manufacturers and are of different vintages. As a result, it is expensive to retrofit automation software to achieve compatibility (Forstner/Dümmler 2014: 199ff). An even bigger challenge for many small and medium-sized enterprises is likely to be to bring about data flow to adjacent internal and external areas in order to enable the exchange of production data horizontally with suppliers and customers and vertically for sales, planning, services or controlling. For SMEs this challenge is particularly great because they have less resources and know-how than large companies (Wischmann et al. 2015: 37). SMEs often do not have their own IT department, which means that the managers themselves have to assess the various Industry 4.0 technologies with regard to their technological maturity and business potential. These differences may also be the reason why small and medium-sized enterprises frequently encounter difficulties in selecting the right solution and complain of a lack of user transparency.

The fact that the networking of production is viewed with some caution by the management of small and medium-sized enterprises is illustrated by the IT Innovation Readiness Index produced annually since 2013. This shows that the senior managements of manufacturing SMEs are more cautious about the issue of Industry 4.0 than production managers who were surveyed (Pierre Audoin Consultans 2015). This reserve on the part of business management is worrying to the extent that the implementation of Industry 4.0 is an extensive task that usually has to be substantially planned and initiated at this level. The task includes the restructuring of processes and company organisation at almost all levels, the adaptation of workers' qualifications and strategic considerations with regard to the development of new business models and the opening up of new markets. Without the impetus and involvement of management the dissemination of Industry 4.0 will be confined within narrow limits. The fact that four out of ten SMEs have no comprehensive strategy for implementing Industry 4.0, while among larger companies the proportion is only two out of ten shows that this shortcoming is characteristic of SMEs (IW Consult/FIR 2015: 32).

4.2 LACK OF STANDARDS AND POOR DATA SECURITY

The reservations of small and medium-sized enterprises with regard to switching to new Industry 4.0 technologies and moving forward with the integration of the various IT systems can also be attributed to the lack of standards and norms, but also to worries about unauthorised access to data. Although progress has been made in the development of standards – for example, by means of Open Platform Communications Unified Architecture – an international standard has not yet been implemented. This would be important for security of investment, however. Secure standards and norms are also a condition of achieving a high number of network partners and thus of unfolding the economic potential of Industry 4.0. At the moment, small and medium-sized enterprises often adapt to the standard of the large company of which they are a supplier. The lack of general standards makes it hard for small and medium-sized enterprises to join value creation networks with different standards and norms and thus narrows their room to manoeuvre. On top of this comes a worry that high investments will have to be written off if they fix on an interface technology that ultimately is not implemented. Thus large parts of the production Mittelstand only adopt Industry 4.0 technologies if there is high CPS interoperability and security by means of standardised interfaces and protocols. An alternative way of overcoming interface problems would be to use higher level cloud services. Downstream services can also be developed and provided via platforms. It is thus alarming that SMEs in Germany make so little use of higher level cloud services and thus deprive themselves of the opportunity of establishing interoperability between different systems. The biggest obstacle to the utilisation of cloud services are security concerns. Clearly, there is a major worry that sensitive company data are not really secure in the cloud and might be accessed by third parties. Further reasons for the neglect of cloud services include uncertainty about the geographical location where the company's data are stored and the applicable jurisdiction (Schröder 2015: 10).

5

TRANSFORMATION OF THE WORLD OF WORK BY INDUSTRY 4.0

The topic of Industry 4.0 was initially addressed almost exclusively from a technological perspective. In the meantime, however, the far-reaching consequences of Industry 4.0 for the world of work are increasingly coming to the fore. In what follows we shall look first at the question of how increasing automation will affect job availability. We shall then look at the possible changes at the company level.

5.1 MACROECONOMIC EFFECTS

Frey and Osborne (2013) depict an, at first, terrifying scenario: a large proportion of human labour could be substituted by machines. According to their calculations at present 47 per cent of workers in the United States are in occupations that, with a high probability, can be automated over the next 10 to 20 years. Bonin et al. (2015) have transposed these studies to the German context and come up with a figure of 42 per cent. They make it clear, however, that this should not be equated with a loss of 42 per cent of jobs. This is because it is not so much occupations as individual activities that will be automated. Taking this into account Bonin et al. (2015) in an alternative calculation come to the conclusion that 12 per cent of all jobs are subject to a high probability of automation.[1]

All these calculations are to be taken with a pinch of salt because they are based on the opinions of experts on automation, who may have overestimated the technological potential (Bonin et al. 2015: 18). Experts on new technologies often fail to take the cost-benefit aspect – in other words, the economic perspective – sufficiently into account. At the same time, workers' uncodeable practical knowledge that cannot be replaced by smart technologies is also underestimated. Indeed, for occupations around Industry 4.0 »practical knowledge« is of the utmost importance to ensure stable production (cf. Pfeiffer/Suphan 2015). Also to be considered is the fact that the rate of diffusion of new technologies partly depends on social, legal and ethical obstacles, so that expectations of a high level of automation within one or two decades could easily be premature (Bonin et al. 2015: 23).

A balanced view of the employment effects of Industry 4.0 should not leave out the fact that its introduction will give rise to new business models that, for their part, will enable employment and productivity gains. The extent to which the number of jobs lost due to Industry 4.0 will be outweighed by new jobs cannot be reliably estimated at present. Some count on overall positive employment effects (cf. BITKOM/Prognos 2013), while other scenario calculations predict a minimal net loss of jobs (cf. IAB 2015).

5.2 WORK ORGANISATION AND STRUCTURING AT THE ENTERPRISE LEVEL

CPS-based production systems will influence the human/machine interface, task organisation and activity structures, as well as, ultimately, enterprise organisation overall (cf. Hirsch-Kreinsen 2014). At present, three scenarios in particular are under discussion with regard to the possible relationship between humans and machines in the Industry 4.0 age (cf. Buhr 2015):

The automisation scenario assumes that the value of human labour will decline and that technology will take over monitoring and control tasks. Human beings as labour power will tend to »come under external control« due to CPS and undertake menial tasks.

In the hybrid scenario humans and machines will work cooperatively. The strengths of human beings and technological applications will be used complementarily in the production process.

In the specialisation scenario CPS will be a tool and play a supportive role, while skilled labour will retain the determinant role.

The automisation scenario is certainly the least desirable. But does that mean it's also the least likely? Even though it's too early to come up with a definitive answer the evidence suggests that purely technology-oriented production, in which human beings play a subordinate role in the production process,

1 In many occupational areas with a high probability of automation there are also activities that would be difficult to automate, which means that a loss of jobs across the board is unlikely.

is not very probable. Despite enormous progress in the performance of digital technology – the oft cited examples of self-driving vehicles and knowledge processing by the computer program IBM Watson – the level of development of »artificial intelligence« remains relatively modest. The examples mentioned by Brynjolfesson/Mc Afee (2014), for example, were achieved at the expense of enormous development costs (around 1,000 person-years) and for very specialised applications (cf. Brödner 2015: 240). As the flexibility of applications increases, however, the levels of complexity will rise exponentially, which means that fully automated production would no longer make sense (Fraunhofer IAO 2013: 53). The intelligence of technological systems is still mapped out by human beings and will not replace the ability of human beings to react flexibly and creatively to unforeseen events (Fraunhofer IAO 2013: 125). Rather it is the practical knowledge or know-how of production workers and their reflective and adaptive capacities that, paired with machine precision and speed, will make Industry 4.0 effective (cf. Brödner 2015). Technology will continue rather to take over repetitive work, activities that are controlled, clearly defined and stable as a process (Fraunhofer IAO 2013: 54). The range of tasks of the future factory worker, by contrast, is changing and will largely consist of the specification, monitoring and safeguarding of production strategies in the cyber-physical production system (Gorecky et al. 2014: 541).

This transformation will work better if the human/machine relationship is designed in a positive way. This means that already during the development of Industry 4.0 technologies we have to think in a human-centred rather than a technology-centred way and strive for user-friendly solutions for production workers. Conducive to this process will be the active involvement of the affected skilled workers in SMEs in the development of networked technological plants and then again in their implementation. The aim is to create intuitive and robust interfaces that make tailor-made information available to cope with issues as they arise and provide human labour with effective support. If such assistance systems are not developed and introduced there is a danger that through the deployment of CPS technologies networking will lead to more complex processes and work will give rise to anxiety, stress or a feeling of overload (Acatech 2012: 109).

The extent to which hierarchies in production will change is unclear (Hirsch-Kreinsen 2014: 3). Because networked production is accompanied by more decentralised planning and governance functions at the operational level part of the former control function could pass to the lower level (Hirsch-Kreinsen 2014: 3). In this way the former activities of production workers could be upgraded.

Due to the increase in real-time data many indirect jobs will be established around production (Fraunhofer IAO 2013: 47). At the same time, as discussed in Section 5.1, simple manual activities will be automated and cease to be performed by human beings (Ingenics/Fraunhofer IAO 2014: 19; Hirsch-Kreinsen 2014: 3). Overall, the effects in question should lead to an upgrading of activities around the production process.

In order to put workers in a position to cope with the new demands there has to be investment in skills development. SMEs in Germany appear to have recognised this. They get their employees to undergo IT further training at a rate higher than the European average (Schröder 2015: 11).

However, not only IT knowledge is relevant. As decentralised planning and control functions increasingly take place at the operative level capabilities for self-guided action and self-organisation will become more and more important (Forschungsunion/Acatech 2013: 57). Small and medium-sized enterprises should thus grasp Industry 4.0 as an organisational innovation. One promising option is the establishment of an environment in the company that puts employees in a position to reflect on the production process and constantly to introduce improvements in it (Fraunhofer IAO 2013: 54).

It can be expected that workers will increasingly have to think in an interdisciplinary way. Not only because Industry 4.0 involves the merging of IT and machinery and machine operators will have to have the necessary IT knowledge, but also because the boundaries of companies will increasingly become blurred. Industry 4.0 also involves the integration of various IT systems along the value chain. Sales staff will be put in a position to set production processes in motion directly from a tablet and to give customers sat next to them real-time production information on the stage of completion of their order. An understanding of processes and their consequences is also an advantage. Networking beyond company boundaries will also require soft skills such as communication capacities to ensure that the process is organised successfully.

5.3 COMPANY INTEREST REPRESENTATION BODIES AS IMPORTANT PARTNERS

It goes without saying that the deployment of Industry 4.0 will also pose some risks for workers. For example, the gathering of more and more data will mean that workers will be increasingly transparent. Although, on one hand, gathering such data will make sense and can be used, for example, for the purpose of ergonomic relief for workers, on the other hand employers might be tempted to use monitoring to subject employees to more performance pressure. Another risk arises from the possibility that it will increasingly be feasible to perform a number of activities independent of location. Although, on one hand, this enhances reconciliation of work and family life, on the other hand there is a danger that the boundaries between private life and work will become blurred, thus adversely affecting the work–life balance.

In order to unleash the full potential of Industry 4.0 in small and medium-sized enterprises the employees will have to have a say in the requisite organisational adaptations. One condition of this is that their concerns arising from the changes will have to be taken seriously by the management. Ortmann and Guhlke (2014) point out that acceptance of technology increases to the extent that it is introduced in a socially and humanly acceptable manner; in other words, if the interests, qualifications and experiences of those involved are taken into consideration in the course of introducing Industry 4.0.

A consensus is more likely to be reached on the further development of qualifications, task allocation and responsibilities already referred to, as well as the concepts of data protection and mobile work, if the representative bodies in the workplace are involved. The latter not only have the trust of the workforce, but also the capacity to deal with this extensive and sometimes conflictual range of issues in a socially acceptable way. The required changes can be subjected to binding regulation by means of company agreements and concerns can be addressed. The challenge, but also opportunity for company codetermination is to anticipate the dynamic and also manifold developments of Industry 4.0 in order to be able to exert a positive influence on them for the sake of the employees.

6

FRAMEWORK CONDITIONS FOR INDUSTRY 4.0

The readiness and ability of the Mittelstand to introduce Industry 4.0 also depends on the framework conditions. The financial environment, the availability of skilled workers, extensive and high-performance broadband access, state support and legal framework conditions are all key factors here.

6.1 FINANCING CONDITIONS

The development and introduction of Industry 4.0 technologies may require substantial investment. Thus the question arises of what financing is available for small and medium-sized enterprises in Germany. Specifically, are there distinct financial barriers that may hinder the extension of Industry 4.0 in the German Mittelstand? To answer this question, we have to differentiate between users and developers of Industry 4.0 technology in the Mittelstand.

Users are typically companies operating in capital intensive and technology-oriented sectors of production. Basically, the financing conditions for such companies are good. Normally, they enjoy a long-term business relationship with a so-called »house bank«. The business fundamentals of their SME customers are well known to such house banks and the credit allocation process is largely problem-free. Little is likely to change in this respect with regard to investments in Industry 4.0 technologies. On one hand, the transition to networked production facilities will occur successively via replacement investments; in other words, old plant will simply be replaced by new networkable plant. Although additional investments in IT infrastructure will often also be necessary, they need not lead to substantial financing problems. It will probably prove helpful that lenders have already broadened their scope to include the evaluation of technological innovations. Specifically, they have built up both their in-house expertise and contacts with consultants and research establishments (Bankenverband/BDI 2015: 4). Furthermore, the creditworthiness of small and medium-sized enterprises in industry has increased again substantially over the past decade due to greatly increased equity ratios and higher profitability (Finanzgruppe DSGV 2015). The current low interest rates and easy credit terms also provide favourable financing conditions.

More difficult are the conditions for young, innovative ICT companies that develop applications for Industry 4.0 that are disruptive rather than incremental and turn them into marketable products. Such companies initially tend to lack a positive cashflow and to be dependent on external capital. For banks, credit allocation is risky, however, because they often do not understand the often entirely new products or business models of young ICT companies and do not receive sufficient collateral. The financing gap can be closed by venture capitalists, however, which often specialise in a particular branch and supply equity capital to selected companies. Their specialisation gives them sector-specific know-how or networks and thus they are able to improve the probability that young, innovative companies will survive. In contrast to banks, venture capitalists take an equity position in the relevant company, rather than receiving interest. Their aim is to sell their stake in the company at a profit after holding on to it for between five and seven years, on average.

The financing environment for ICT companies has improved recently. The ICT sector has been able to attract venture capital to a disproportionate extent. In 2014, 25 per cent of all German venture capital went to ICT companies. Berlin, for example, has developed into a hotspot, attracting more than 37 per cent of all venture capital investment (BVK 2015: 15f). Despite this gratifying trend, however, the provision of venture capital in Germany remains at a low level by international comparison of innovation-based economies. Although the framework conditions with regard to early-stage financing have improved substantially due to public support measures – such as the High-tech Gründerfonds (start-up fund) and the INVEST subsidy – capital is still lacking for the subsequent growth phase. The German government is seeking to address this by means of a new legislative initiative. Various proposals and measures are currently under discussion. They include less restrictive tax regulations with regard to the treatment of losses carried forward (§8 Körperschaftssteuergesetz KSTG – German Corporation Tax Act). At present, losses carried forward cannot be taken over by an investor who acquires a company. This restrictive treatment of losses carried forward has a negative effect on the willingness of venture capitalists to invest in young, innovative companies (EFI 2015:

34). It remains to be seen to what extent it will prove possible to create competitive tax conditions for venture capitalists in Germany and, by means of opening clauses, additional investment possibilities for insurance companies and pension funds.

6.2 AVAILABILITY OF SKILLED WORKERS

A qualified workforce is indispensable for the development, introduction and utilisation of Industry 4.0. The technical knowledge required for each of these phases is currently very high in Germany, recruited primarily from the so-called MINT subjects (mathematics, informatics, natural sciences and technology). World Economic Forum experts attest that German education in mathematics and natural sciences is of high quality by international comparison (BMWi 2014: 49). However, for some years the number of graduates in MINT subjects has fallen short of demand. This development has led to a shortage of skilled workers in occupations crucial for the implementation of Industry 4.0, such as electrical engineering, informatics and software development. These days it takes over 110 days to fill a vacancy in these shortage occupations (Bundesagentur für Arbeit 2015: 7). There is a labour shortage even in non-academic technical occupations, such as mechatronics and automation technology, which could hinder swift migration to networked production. The extent to which this bottleneck will continue into the future remains unclear. On one hand, demographic change and increasing demand for such occupations suggest that this trend will continue or even get worse. On the other hand, the number of MINT students has been rising for some years. For example, student numbers grew by around 50 per cent between 2007 and 2015, which could alleviate the skilled labour shortage. However, it remains a challenge for small and medium-sized enterprises to assert themselves both against large companies and rival small and medium-sized enterprises when it comes to filling vacancies in these areas. For universities the task is to adapt their courses, especially in engineering, but also in informatics and to open up courses to more interdisciplinarity in order to strengthen the competences required to deal with hybrid Industry 4.0 technologies. The same applies to in-house staff training and occupational training (apprenticeships). New job profiles that bring information and production technologies closer together – for example, training as an industrial IT specialist – are worth considering in this context (Fraunhofer/IAO 2013: 126).

6.3 COMPREHENSIVE BROADBAND INFRASTRUCTURE

Fast and more secure data connections are a basic condition for the realisation of Industry 4.0. Broadband provision in Germany is in the upper mid-range by international comparison, but it is a cause for concern that the International Telecommunication Unit (ITU) already defines a transfer rate of at least 2 Mbit per second as a broadband connection (BMWi 2014: 52). This transmission rate is far from adequate for organising inter-company internet-based production or downstream services, such as the evaluation of real-time data. Stable high-speed transmission paths over fibre optic cable are needed for that. Germany, with a fibre optic coverage of only 1 per cent, brings up the rear among European countries (BMWi 2014: 50). Small and medium-sized enterprises, especially in production, are often located in rural areas, where there is virtually no fast fibre optic cable. The need for action to raise fibre optic coverage in a short time in order to unleash the potential of Industry 4.0 for the Mittelstand, is correspondingly great. Although according to the government's plans extensive broadband coverage of over 50 MB per second is to be available by 2018, this is possible only by means of vectoring technology. At least on the basis of copper cables, this technology can be only an interim solution because the achievable transmission speeds will not be sufficient in the future and the vectoring effect in copper cable decreases with length. This is compounded at present by the fact that only one telecom provider can offer such a service. This threatens competition and thus more cost effective broadband provision. There is no medium-term alternative to expansion of fibre optic coverage, given the state of current technology. Otherwise smart factories are not feasible. The fibre optic network must therefore be expanded as a matter of urgency.

6.4 STATE SUPPORT

State support in Germany for specific Industry 4.0 projects, at least 450 million euros for a period of five to seven years, is already relatively extensive, according to the findings of a recent analysis by Agiplan, Frauenhofer and Zenit (2015: 34ff). The spectrum of supported technology is generally fairly broad. Nevertheless, thematic foci can be identified, based on the amount of funding and the number of projects receiving support, in the research areas of autonomous systems, hardware development and assistance and visualisation systems. Software development also receives considerable support. However, according to the authors the focus of support in relation to software development should be shifted towards interoperable, open, sustainable and secure software platforms; for example, a platform for »Industry 4.0 apps«.

Overall, the field of application of supported Industry 4.0 technologies lies in production and only to a lesser extent in auxiliary activities, such as logistics, maintenance and product development. Prospectively, these adjacent value creation processes should receive more support in order to boost microeconomic and macroeconomic use of Industry 4.0 across the board.

Support programmes are directed largely towards small and medium-sized enterprises, although large companies are not excluded. Making an application requires detailed administrative knowledge, however. This and the cost of organising joint research projects is often too much for SMEs. Options for simplifying the application process should therefore be taken advantage of (Agiplan/Fraunhofer/Zenit 2015: 197). Similarly, existing measures should be packaged and made more transparent. Finally, putting research results into practice, among other things by demonstrators and prototypes, is also recommended.

Government has already responded to the latter demand and put the competence centres for Industry 4.0 proposed by Agiplan, Fraunhofer and Zenit (2015: 187 ff) out to tender. The five competence centres are supposed in particular to mobilise the Mittelstand for Industry 4.0. Their main task will be, from 2016, to submit information and consultation offerings and to support small and medium-sized enterprises in the implementation of new Industry 4.0 technologies. Close cooperation with the relevant chambers and associations is supposed to ensure regional access to information and to lower the threshold for companies to deal with the issue. Overall, government policy is on the right track to raise the awareness of small and medium-sized enterprises with regard to Industry 4.0 and, by means of the abovementioned measures, to provide the impetus towards implementation.

6.5 LEGAL FRAMEWORK

The data generated, stored, utilised and transferred in the course of automation, like the deployment of new application technologies or product liability, give rise to numerous legal issues. Although these emerging issues are not really new, they can be very complex. On top of that, adjustments required by law cannot be brought about as rapidly as new technological developments and procedures can be implemented (Tschohl 2014: 220). Legal uncertainties, furthermore, are compounded by the networking of small and medium-sized enterprises with foreign companies. Although legal uncertainty can often be substantially reduced by drafting contracts appropriately, the complexity of the issues to be regulated represents a barrier to investment for small and medium-sized enterprises, especially those without their own legal department. The legal challenges include the following aspects, among others (cf. Forschungsunion/Acatec 2013: 62 ff):

Protection of corporate data
Data exchange between companies makes it possible for third parties to obtain an insight into their business strategies. It must therefore be clarified to whom the generated data belong and who is entitled to use them. In cases in which the legal protection is insufficient from the company's standpoint individual contracts can be concluded. However, having to conclude a large number of contracts can be an unreasonable expense for individual companies.

Liability
Who is liable for faulty products? Networked production means that the attribution of sources of error is not a simple matter without implementation of corresponding regulations on traceability procedures. Furthermore, it will have to be clarified contractually who is responsible for damages, and to what extent, when autonomous systems generate inaccurate data or data are accessed by unauthorised third parties.

Handling personal data
The control of technical assistance systems can require the collection of personal data, whose protection and confidential use must be ensured.

Trade restrictions
Particular systems deployed in Industry 4.0 may be subject to international trade restrictions. One example is the use of encryption techniques to ensure the security of CPS data transfer. The import of cryptography products from other countries sometimes requires authorisation and its export restricted by the EU.

Small and medium-sized enterprises should be made aware of the legal issues that accompany Industry 4.0 and provided with legal support. The implementation recommendations made by Forschungsunion and Acatech (2013, 2015) propose support, especially for SMEs, in the form of practical guidelines, checklists and specimen contract clauses. In addition, harmonisation of data protection law, as well as globally uniform regulations on trade restrictions should be the medium- to long-term aim.

It is therefore clear that promoting new Industry 4.0 technologies should also take account of law as a cross-cutting issue in order to bring about the fastest possible dissemination among small and medium-sized enterprises. As was already the case in the BMWi-backed project »Autonomik und Industrie 4.0« other support measures should be provided with accompanying legal research. Hilgendorf (essay in Agiplan/Fraunhofer/Zenit 2015: 139 ff.) proposes that practically-oriented Industry 4.0 research projects should generally also look into the relevant legal issues. Following on from that, practicable solution strategies should be developed that can be offered to SMEs as a reference model.

7

SUMMARY

The economic potential of networked production in terms of Industry 4.0 is already discernible in the basic technologies currently available. It can be foreseen that the dynamic technological developments will give rise to substantial advances in productivity for many smaller Mittelstand enterprises, too. In order to realise them, small and medium-sized enterprises require flexible organisational structures because business areas that at present are clearly separated from one another are increasingly becoming interconnected. The managements of small and medium-sized enterprises must therefore try to find out how much smarter their product range can be made by CPS and which new business models might emerge from that. Smart products can increase the proportion of value-added from product sales to downstream services. The consequences of this should be reflected in the strategic thinking of small and medium-sized enterprises. It can be expected that in future small and medium-sized enterprises will (have to) call in external expertise more frequently, whether with regard to decisions on IT investments or the identification of relevant technological trends.

Other challenges associated with Industry 4.0 can be handled by small and medium-sized enterprises only to a limited extent. A key factor for the dissemination of Industry 4.0 will be the development of secure, standardised interfaces. The standardisation process has picked up speed due to the work of the DKE/DIN standardisation roadmap and the Reference Architecture Model Industry 4.0 (RAMI 4.0). In order that the interests of small and medium-sized enterprises will be taken into consideration it would be helpful if they were more closely involved in the ongoing standardisation process. It is to be hoped that the standardisation work of the DKE/DIN, together with international bodies, will smooth the way for open international standards. If this does not occur, or only one or two major companies with closed standards become established, the danger is that SMEs will lose their share of value-added to such companies because the availability of data will make up a considerable part of future value creation.

Overall, the framework conditions for Industry 4.0 in Germany can be considered largely positive. The authorities, by promoting Industry 4.0 technologies and cross-cutting issues and providing support for implementation and awareness-raising, have begun to tackle major challenges or are on the verge of implementing appropriate measures. One example are the planned Industry 4.0 competence centres, which will engage in application-oriented research and, at the same time, with network partners, offer consultation services to small and medium-sized enterprises.

The biggest shortcoming at present is the lack of comprehensive broadband connections to ensure very fast transfer rates without loss of quality. This problem affects small Mittelstand companies in particular. While large companies have the resources to connect, if necessary, to a reliable internet infrastructure, large parts of the Mittelstand are reliant on the network expansion of telecom providers or on state support measures. A second important area is training. In order to adapt them to the requirements of Industry 4.0 an interdisciplinary linking of curricula is needed in the relevant subjects. The tried and tested dual training system, with its linking of theoretical learning content and timely practical application in companies can support the transformation to networked production in an appropriate manner. However, the new requirements mean that modifications are needed in training regulations to link content from IT and industry. It may even be that new training occupations will emerge. Against the background of Industry 4.0 the extent to which state support for further training can be expanded has to be assessed. Financial incentives could contribute to encouraging workers to upgrade their qualifications to meet new requirements on their own initiative.

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