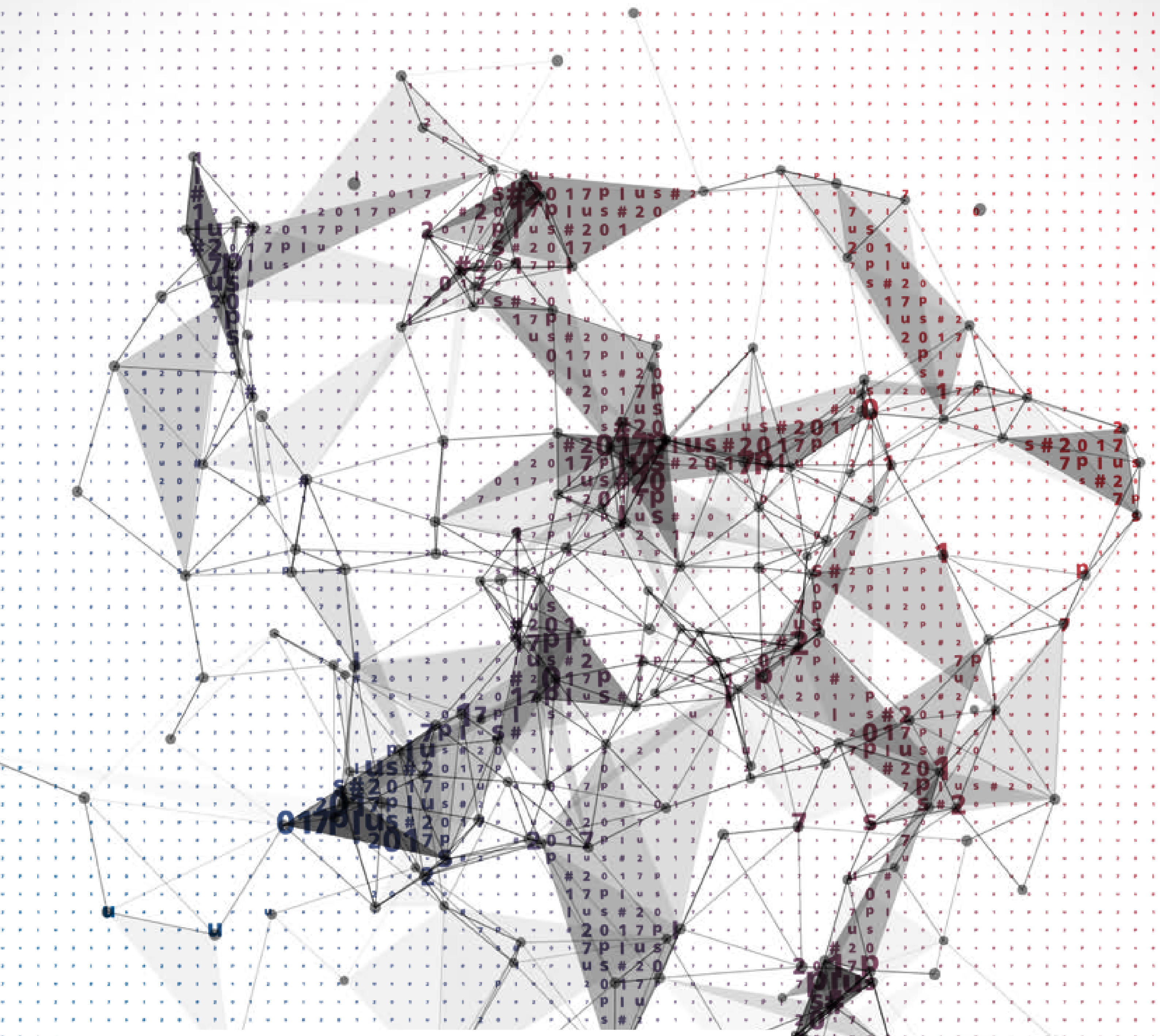

Daniel Buhr

Social Innovation Policy for Industry 4.0

good society –
social democracy
2017 plus

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good society –
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2017 plus

A PROJECT BY THE
FRIEDRICH-EBERT-STIFTUNG
2015 AND 2017

What is a Good Society? For us this includes social justice, environmental sustainability, an innovative and successful economy and an active participatory democracy. The Good Society is supported by the fundamental values of freedom, justice and solidarity. We need new ideas and concepts to ensure that the Good Society will become reality. For these reasons the Friedrich-Ebert-Stiftung is developing specific policy recommendations for the coming years. The focus rests on the following topics:

– A debate about the fundamental values: freedom, justice and solidarity;
– Democracy and democratic participation;
– New growth and a proactive economic and financial policy;
– Decent work and social progress.

The Good Society does not simply evolve; it has to be continuously shaped by all of us. For this project the Friedrich-Ebert-Stiftung uses its international network with the intention to combine German, European and international perspectives. With numerous publications and events between 2015 and 2017 the Friedrich-Ebert-Stiftung will concentrate on the task of outlining the way to a Good Society.

For more information on the project:
www.fes-2017plus.de

The Friedrich-Ebert-Stiftung

The Friedrich-Ebert-Stiftung (FES) is the oldest political foundation in Germany. It was named after Friedrich Ebert, the first democratically elected president of the German Reich. As a political foundation our work is oriented towards the fundamental values of social democracy: freedom, justice and solidarity. As a non-profit institution we act independently and wish to promote a pluralist social dialogue about the political challenges of today. We consider ourselves as a part of the social democratic community of values and the German and international trade union movement. With our work we encourage people to take active roles in society and advocate social democracy.

About the author Daniel Buhr

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Daniel Buhr

Social Innovation Policy for Industry 4.0

Preface

The term "Industry 4.0" was first introduced by the German Industry-Science Research Alliance (Forschungsunion) in 2011. It refers to digitising industrial production. The concept outlines the vision of a smart factory, which is characterised by the complete networking of all production parts and processes: real time control via ITC and the increased use of robots, which control themselves, are developments that should contribute to greater productivity through resource efficiency. The shift is already under way and the concept of Industry 4.0 is shaping the digital discourse in Germany.

Convergence of production and interaction, work and communication are increasingly interdisciplinary competencies for staying economically competitive. In addition to expert knowledge, flexibility, creativity and innovation, these are critical success factors for companies and their employees. For companies and businesses, however, these competencies do not just appear out of nowhere. Industry 4.0 also needs to be promoted through appropriate innovation policies. However, it is not only a task for the state. Just like government officials, the stakeholders from civil society, business and the sciences have to develop a systematic understanding of innovation in order to usher in comprehensive digitalisation processes for enterprises.

The changes brought about by networking and the use of data have a far greater impact than for industrial production alone. To a large degree, they call fundamental elements of the world of work and production into question. They affect our economies and our social life as a whole.

We are at the beginning of a fundamental debate that is still raising more questions than offering answers. This situation incited the Friedrich-Ebert-Stiftung to hold a series of expert discussions about the impact of Industry 4.0. We are pleased to present the results of this study, which were put together by Prof Dr Daniel Buhr of Eberhard Karls University in Tübingen. His central message is: the answers to the profound upheavals ahead can only begin to be forged when Industry 4.0 is defined and grasped as more than a technical innovation – it has to be seen as a social innovation as well.

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INTRODUCTION[1]

Industry 4.0 is currently more a vision than a reality, but it is already poised to change not only the way we do business, but our social cohesion in general.

Digitisation continues its progress and with it machines are taking over ever more activities – in the production halls of Detroit and Bochum as well as in China, Vietnam and Bangladesh. But it is still people who develop machines and who are the ones putting them to work. Hence, while traditional production methods and factors of production recede, innovators are moving forward. New organisational methods, new products, new services, new distribution channels and business models are in demand.

It is within the context of these developments that the following central policy questions arise:

– How can we promote the evolution of new products, services and business models?
– And how can we ensure that as many people as possible benefit from these developments and not just a small group?

The race for the best ideas in business, politics and society has already begun. But its track has been a technological one so far. This is a mistake. If we want to take hold of the opportunities that digitisation presents, we have to recognise its potential for society on the whole. It is in this "second machine age" that humans will take the charge as developers, designers and co-producers (Brynjolfsson et al. 2014). Therefore, we have to look more closely at the social innovations alongside the technical ones. Social innovations, on the one hand, are new practices to tackle social challenges, which affected persons, groups and organisations come to accept and employ. On the other, they also facilitate diffusion and dissemination of many technical developments.

This is especially true for Industry 4.0. The vision: people, things, processes, services and data – everything will be networked. Driven by the Internet, the real and virtual worlds are beginning to merge. Smart objects, equipped with actuators and sensors, with QR codes and RFID chips, will soon steer themselves through the smart factory and even along the entire value chain from product development to service. Production is thereby distributed, becoming more flexible and faster. In the future, all of the relevant information could be available to all the humans and machines involved in real time, i.e., both the customer as well as any business partners. This allows for dialogue between producer and consumer so that individual customer wishes can be better fulfilled. The vision that industrial (mass) manufacturing facilities could also have limited one-off or tailored production series will be a reality. Along with it come efficiency gains and productivity improvements, because the resources can be used very effectively.

Thus, production not only becomes smarter, but more sustainable too. There is already a lot of talk about a "fourth industrial revolution", because growing digitisation is already putting pressure on traditionally successful business models and allowing the fruition of completely new models. Hence, many opportunities come with these new developments, but so do many risks and challenges for business as well as civil society. Some of these are the growing delimitation of work and unresolved issues of data privacy, protection and security. Furthermore, certain jobs may be made redundant through automation. Qualification requirements will multiply and whole new tasks will arise.

This study aims to present the opportunities and challenges to lay the groundwork for making recommendations regarding the central question: What can policy-makers do to support the shift toward Industry 4.0? The answer to this question will be detailed in ten points that have come out of existing studies as well as the results of a series of expert discussions on Industry 4.0 conducted by the Friedrich-Ebert-Stiftung. In 2014, four discussion rounds were held with 50 participants to discuss important aspects of Industry 4.0. The series focused on four key questions, which guide this study:

– What is Industry 4.0?
– What impact does it have on certain industries and companies?
– What does this mean for the world of work?
– What demands does Industry 4.0 place upon technology, research and policy?

1 The author would like to thank the Friedrich-Ebert-Stiftung team, Dr Philipp Fink and Patrick Rüther and Heinrich Tiemann, former Secretary of State, and Dagmar Bornemann, Executive Board Member of the Friedrich-Ebert-Stiftung's manager association, for their valuable advice. This publication is a translation of Daniel Buhr: Soziale Innovationspolitik für die Industrie 4.0, WISO Diskurs, Friedrich-Ebert-Stiftung, Bonn 2015.

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ANALYSIS

2.1 WHAT IS INDUSTRY 4.0?

Industry 4.0 is the vision of increasing digitisation of production. The concept describes how the so-called Internet of things, data and services will change in future production, logistics and work processes (Acatech 2014). In this context, industry representatives also like to talk about a fourth industrial revolution. They are alluding to a new organisation and steering of the entire value chain, which is increasingly becoming aligned with individual customer demands.

The value chain thus has to cover the entire lifecycle of a product, from the initial idea through the task of developing and manufacturing it to successive customer delivery as well as the product's recycling, all the while integrating the associated services. A variety of different use cases is possible (figure 1).

Figure 1
Use cases for Industry 4.0

Use case 1: Resilient factory (source: Festo) Resilience means resistance, but also agility, adaptability, redundancy, decentralisation and ability to learn. In a resilient factory, a wide range of products with custom features has to be produced in highly seasonal demand. Just-in-time production at optimum capacity is achieved through a situational adjustment of production lines.

Use case 2: Technology data marketplace (source: TRUMPF) A laser machine allows for unique consumer parts to be cut from metal sheets. The technical data that the machine has access to cannot deliver the needed quality, however. Neither the material nor the time is available for a classical optimisation of the data to direct the laser cut. Quality is achieved via access to internal and external technology know-how, and the order is carried out on schedule.

Use case 3: Intelligent maintenance management (source: wbk) The indirect costs of unplanned machine downtimes can considerably exceed the direct costs for any maintenance or repairs. Anticipatory maintenance concepts allow for the operator to significantly reduce the costs of unplanned shutdowns.

Use case 4: Networked production (source: iwb) Megatrends such as the individualisation of products along with a turbulent market together lead to complex production processes. Due to these boundary conditions, organisational losses have to be avoided with adequate planning and control of production, to further develop Germany's manufacturing companies' competitiveness.

Use case 5: Self-organising adaptive logistics (source: Daimler) In networked production, reliable production logistics processes are crucial for friction- and error-free production processes. The requirements for the number of items and variant flexibility will continue to rise in the future, where bottlenecks and supply failures will be more likely. CPS allows for transparency in material and part logistics. It serves as the technical foundation for a dynamic intra-logistic controlling in flexible factories.

Use case 6: Customer integrated engineering (source: IPA) The ever further-reaching customer requests, adherence to deadlines and late changes are driving the need for a fundamental shift in the interplay between classical production tasks and the consumers or the supply chain. Integrating customers in the developing, planning and value-added activities of the contracted company results in novel transparency and a reactive production in perfect synchronisation with all the participants.

Use case 7: Sustainability through up-cycling (source: IPA) Rising commodity prices drive up overall product prices. Especially for high-tech products, the raw materials are often also a limiting factor (e.g., rare earth metals or platinum). By only selling product usage, a company retains ownership of the raw materials. This only becomes useful, however, when the manufacture, assembly and recycling information is built into the product. Up-cycling could often replace product down – or recycling when comprehensive information about the product components is provided.

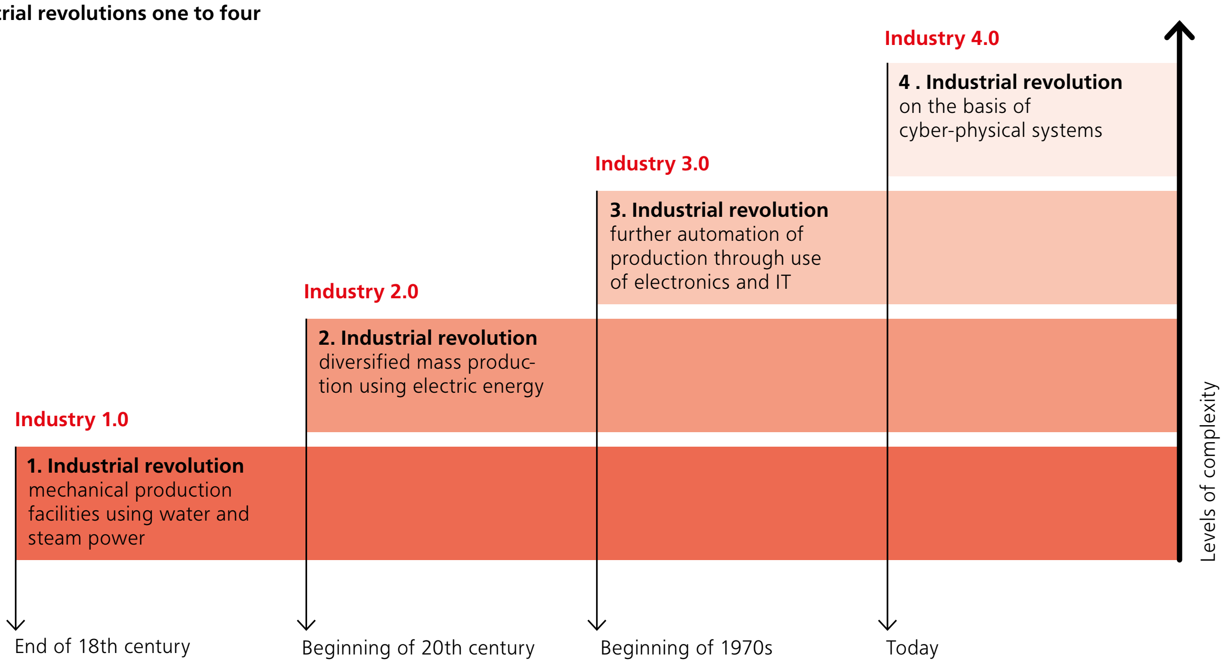
Use case 8: Smart factory architecture (source: IPA) Along with the idea of a product's lifecycle, many companies have already begun thinking about the factory's lifecycle. It is striking how difficult synchronising these lifecycles actually is. Analogous to these lifecycles, a smart factory has its own lifecycle that can be designed in accordance with the product. The smart factory offers an opportunity to establish a comprehensive lifecycle by integrating an HTO approach with IT on a meta level.

Source: Forschungsunion/Acatech 2013: 105 et seq.

Growing digitisation provides the launch pad from which we are lifting off into the "second machine age" (Brynjolfsson/McAfee 2014a). This is due to the fact that data forms the material of this fourth industrial revolution (see figure 2). In the future, data will be ubiquitous and omnipresent. Whoever can access this limitless data treasure, will benefit enormously, above all from flexibility and efficiency. Industry 4.0 could become a result of this ongoing digitisation in which everything along the value creation chain is networked and all of the relevant information can be independently and directly exchanged between the individual chain links. Linking people, objects and systems can lead to dynamic, real-time-optimised and self-organising, cross-company value added networks that can be optimised according to different criteria, for example cost, availability and resource consumption (Plattform Industrie 4.0 2014: 1). Thus, the vision is about efficiency in its purest form: maximum flexibility with the perfect flow of value creation.

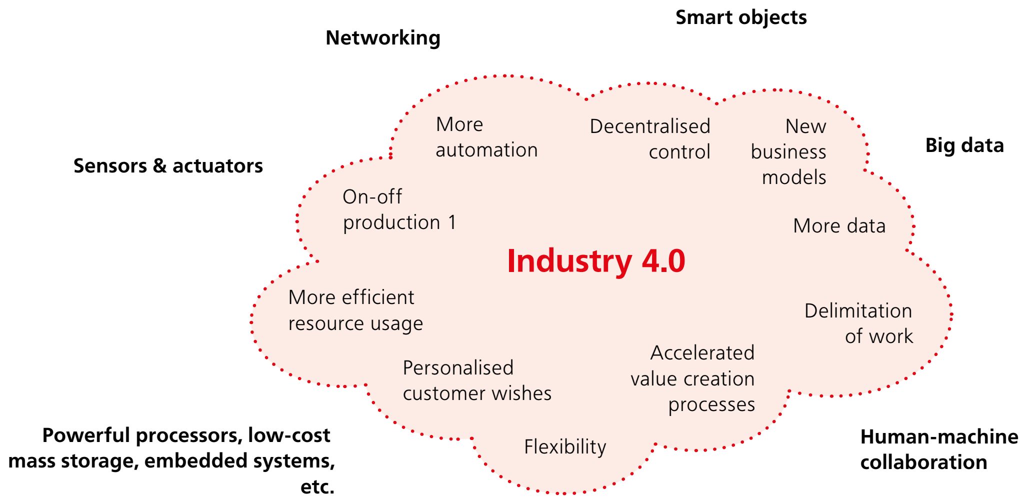
In the future, the objects could communicate with each other directly and independently (see figure 3). They consult one another about what should happen to them next. This means that objects will become machine-readable. Even those that have yet to be outfitted with electronic components will receive their own IP addresses. Internet protocol IPv6 makes this possible, as it offers a much greater number of potential addresses and easier encryption as well as authenticity verification.

Figure 2
Industrial revolutions one to four



Source: Fraunhofer IAO 2013.

Figure 3
Industry 4.0 drivers and their consequences



Source: Forschungsunion/Acatech 2013: 105 et seq.

Figure 4
Opportunities for growth with Industry 4.0

Economic sectors	Gross added value (in billions of euros)		Potential from Industry 4.0	Annual increase	Increase (in billions of euros)
	2013	2025	2013–25	2013–25	2013–25
Chemical industry	40.08	52.10	+30.0%	2.21%	12.02
Motor vehicles and automotive parts	74.00	88.80	+20.0%	1.53%	14.80
Machinery and facility engineering	76.79	99.83	+30.0%	2.21%	23.04
Electrical equipment	40.72	52.35	+30.0%	2.21%	12.08
Agriculture and forestry	18.55	21.33	+15.0%	1.17%	2.78
Information and communication technology	93.65	107.70	+15.0%	1.17%	14.05
Joint potential of the 6 selected branches	343.34	422.11	+23.0%	1.74%	78.77
Exemplary extrapolation for the total gross added value in Germany	2,326.61	5,593.06**	+11.5%**	1.27%**	267.45**

* No economic growth is taken into account in these projections for 2025. It is a purely relative observation of the potential with and without Industry 4.0 for the six selected sectors.
** The total includes the potential for Industry 4.0 for the six selected sectors as well as the projection for the remaining sectors under the assumption that the six sectors amount to 50% of gross added value.

Source: BITKOM/Fraunhofer IAO 2014: 36.

Thus, products will be able to tell us many things. Sensors and actuators will ensure that the data from scanners and computers can be distributed and processed directly. The Internet of things and services is the result and it promises to merge the physical and the virtual world into what are known as cyber-physical systems (Plattform Industrie 4.0 2014).

2.2 IMPACT ON ENTERPRISES AND SECTORS

The guiding theme of the developments outlined above seems to be: "anything that can be digitised will be digitised". Accordingly, the scenarios of future developments are pretty ambitious. The conceptions of how Industry 4.0 is to affect companies and sectors, economies and societies differ greatly. They can be summarised, however, into three perspectives (Stephan 2014):

1 Disruption: Industry 4.0 enables completely new business and value creation models;
2 Progess: Industry 4.0 solves the problems of today with the technologies of tomorrow;
3 Destruction: Industry 4.0 is not new and lacks innovative approaches.

It is still unclear which path Industry 4.0 will take, but the current discourse is dominated mainly by representatives of the progressive and disruptive conceptions. They emphasise the opportunities:

– Real-time networking of industrial processes makes production cheaper, sustainable and efficient.
– Digital networking allows the direct involvement of customer demands and the cost-effective customisation of products and services.
– The world of work could be made more humane.
– Beyond all that, Industry 4.0 could provide enormous potential for new products, services and solutions that could enrich people's everyday lives.

This positive expectation expresses itself in the corresponding forecasts[2] and calls for investment: for the EU to maintain its status as an important industrial centre, companies need to invest around €1.35 trillion into Industry 4.0 throughout the EU over the next 15 years. That would amount to at least €90 billion per year (Roland Berger 2014: 15). On top of that, there would have to be major public-works investment like the urgently needed accelerated broadband in Germany.

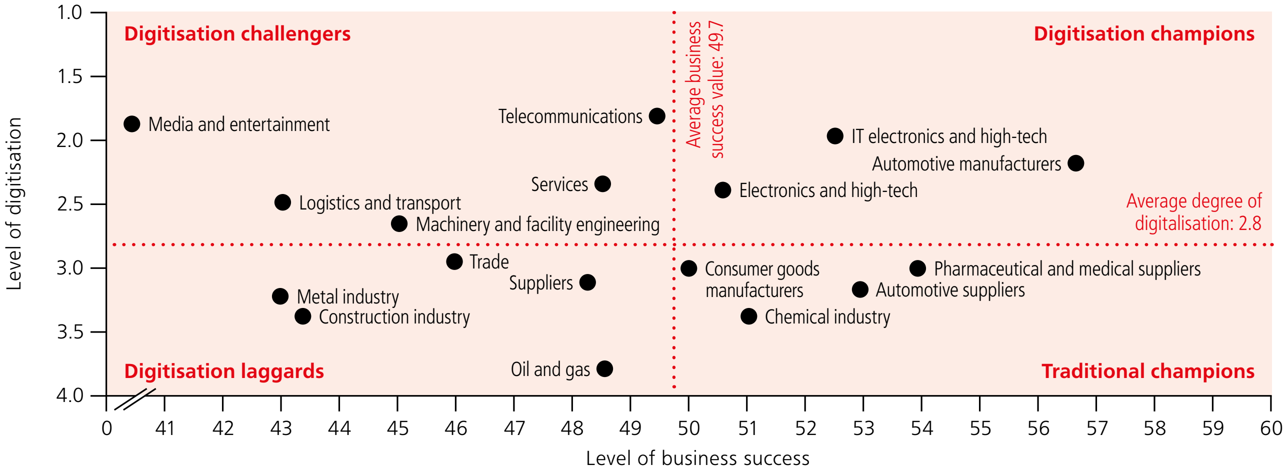
Of course, the IT and TC sectors will be the first to see the benefits. Creators and providers of software solutions for big data analysis, networking and digitisation can most likely look forward to increases in orders. Many more industries, however, will probably be deeply impacted by Industry 4.0 developments very soon: machine and facility engineering, electrical equipment manufacturers, the chemical industry, car makers and their suppliers, but also the logistics industry as well as agriculture.

In a study for the industry association BITKOM, Fraunhofer IAO estimated productivity gains of around €78 billion in six sectors over a period of almost ten years (see figure 4). A yearly sectoral average of 1.7 per cent could be achieved as additional gross added value (BITKOM / Fraunhofer IAO 2014).

Opportunities for certain people can be pitfalls for others. The traditional industrial leaders could quickly find themselves in the role of mere suppliers, who are completely interchangeable, if they are unable to provide consumers with custom-fit "smart services". Open innovation processes, integration of (end) customers in the design and production process along with

2 See e.g., Accenture (2014), DZ Bank/GfK Enigma (2014), BITKOM/Fraunhofer IAO 2

Figure 5
Business success and degree of digitisation according to sector



The business success in the period between 2008–2012 is calculated as a value based on the average annual sales growth and the average profitability (measured as revenue and return on equity); rating scale 100 = highest value and 0 = lowest value; the digitisation level is measured as value based on the digital frameworks, digital strategy, digital supply and digital processes and the other sub-criteria; rating scale 1 = most, 2 = some, 3 = little, 4 = partially digitised, all values are calculated as unweighted averages.

Source: Accenture 2014: 13.

targeted big data analytics enable a variety of new business models and thus put the time-tested ones under considerable pressure. This is also the case in Germany, particularly in the sectors responsible for the success of a "coordinated market economy" (Hall/Soskice 2001), e.g. machinery, facility and vehicle engineering. A major proportion of turnover for these industries is earned via sales of spare parts, upgrades and services. Over the years, providers have built a dense network of sales, service and customer service partners in order to have as much direct access to their customers as possible. Industry 4.0, however, taps into intelligent software with appropriate data analysis at the existing interface between manufacturer and customer, allowing for new entrants to the market: providers will thus offer manufacturer-spanning services, preventive maintenance and quick supply of spare parts.

Following the idea of the fourth industrial revolution, it is apparent that the process of digitisation will transform many things. This explains the prevalence of the term Industry 4.0 in the public media. It is striking, however, that large sections of society have yet to deal with this issue very intensively. It is a technical term today, one that concerns mostly the economy. Nevertheless there are vast differences here as well – aside from a vanguard of pioneer companies, these developments remain so far rather abstract for most firms. Thus, 90 per cent of the members of the Federation of German Industries (Bundesverband der Deutschen Industrie, BDI) recognise the greatest challenges posed by Industry 4.0 for the future, but only 12 per cent feel prepared (Klein 2014).

This can already be seen in their respective levels of digitisation (see figure 4) and remains quite divergent within the German economy according to industry and company size (Accenture 2014; DZ Bank/GfK Enigma 2014).

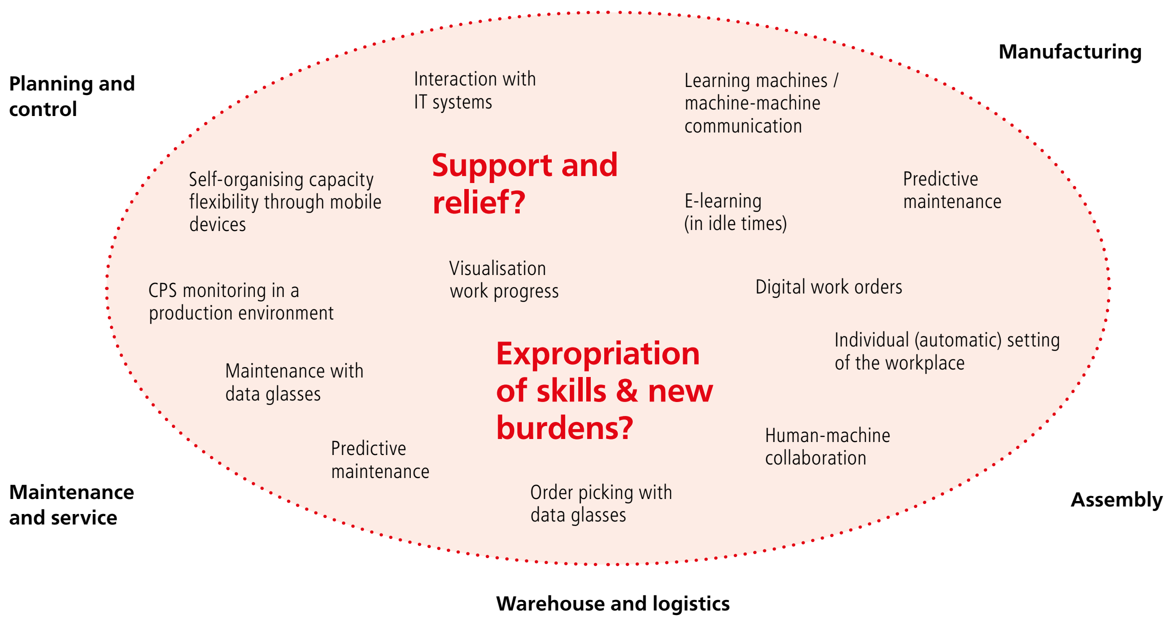
Put succinctly: the bigger the company, the more it takes digitisation seriously. This means that many small and medium-sized companies are far behind. Just under 70 per cent of companies with an annual turnover of less than € 5 million indicated that digital technologies play only a minor or no role at all in their processes of value creation today. Figure 5 shows that especially the metals, chemical and construction industries, but also the trade sector lag behind in digitisation (Accenture 2014).

Especially in view of the persistently weak willingness to invest in Germany, many studies and analyses[3] are putting high expectations on the fourth industrial revolution. Thus, today only about every fifth company has a high degree of digitisation – in five years this will account for more than 80 percent of all enterprises (according to the respondents' own statements). The forecast is therefore that the German industry will be spending an annual €40 billion in Industry 4.0 solutions up through 2020. That would amount to about 3.3 per cent of the country's yearly turnover (PwC 2014). The study puts forth three drivers for the abovementioned investment volume:

1 increased capacity to control horizontal and vertical value chains (productivity improvements by more than 18 per cent over the next five years);
2 the increasing digitisation and networking of a company's products and services will contribute to ensuring competitiveness, leading to an expected increase in annual sales of 2–3 per cent on average or €30 billion per year;

3 In the German context these are the Federal Ministries for Economic Affairs and Energy (BMWi), Education and Research (BMBF), Transport and Digital Infrastructure (BMVI) and the Ministries of the Interior (BMI), Labour and Social Affairs (BMAS), Health (BMG), as well as the Ministry of Family Affairs, Senior Citizens, Women and Youth (BMFSFJ).

Figure 6
Typical applications of human-machine interaction



Source: Kurz 2014.

3 new business models arising from increased cooperation over the entire value chain as well as the integrated use and analysis of data that allow for the satisfaction of even the most individual customer needs.

2.3 INDUSTRY 4.0 AND ITS CONSEQUENCES FOR THE WORLD OF WORK

What do these developments have in store for people and society? Let us begin with the world of work. Today, the following trends are already emerging:

1 The organisation of work is becoming more flexible in terms of time and space.
2 Work processes are ever more digitised, more decentralised and less hierarchic.
3 Work processes are becoming more transparent.
4 Ever more routine activities are digitised and automated (see Münchner Kreis 2013; Picot/Neuburger 2014).

So far in the public discourse, it is rather the progressive and disruptive perspectives on Industry 4.0 that seem to have prevailed, touting above all the opportunities – while the impacts on the labour market are clearly controversial. The anxious question is: Will increasing digitisation reduce the number of jobs in manufacturing? There is no definitive answer to this question at the moment. The estimates (see figure 6) are too uncertain and differ widely.

At least one finding has already prevailed. Contrary to the discussions of the 1980s, today it is no longer about human versus machine. Rather, most of the scenarios revolve around a more complex relationship between humans and machines (Kurz 2014; Ganz 2014):

1 The **automation scenario**: systems direct humans. Monitoring and control tasks are taken over by technology. It prepares and distributes information in real time. Employees respond to the needs of cyber-physical systems (CPS) and take on primarily executive tasks. The abilities of lesser skilled workers are thereby devalued (see figure 7).
2 The **hybrid scenario**: monitoring and control tasks are performed via cooperative and interactive technologies, networked objects and people. The demands on employees increase because they have to be considerably more flexible.
3 The **specialisation scenario**: people use systems. CPS is a tool to support decision-making. The dominant role of the qualified workers is maintained (see figure 7).

EFFECTS AT THE MACRO LEVEL: THE LABOUR MARKET

Digitisation and Industry 4.0 will massively change work in the future. Automation will enable ever-smaller series production (one-off production) – labour will nevertheless continue to be an important part of production. Thus, Industry 4.0 means much more than connectivity. The future includes intelligent data acquisition, storage and distribution by objects and people. Traditional production-line workers' and knowledge workers' tasks will amalgamate to an ever greater degree (Fraunhofer IAO 2013). As a result, many labour processes will be carried out more efficiently and effectively in the future. The processes will also provide a variety of new assistance systems. This means that administration and production processes will be further automated as well. A variety of options will open up to certain work processes and labour groups (especially the highly qualified) to design their

Figure 7
Qualification requirements for Industry 4.0

Automation scenario

- **Monitoring and control technology**
- **CPS directs employee (primarily performing actively)**
- **Highly qualified personnel for installation, modification and maintenance of the CPS**

Labourers

Mid-level employees: ⇩

Specialised employees: ↑

Highly qualified: ↑

Specialisation scenario

- **CPS support decisions**
- **Employee directs CPS**
- **Skilled personnel retain dominant role**
- **More informational, organisational, mechatronic content**

Labourers

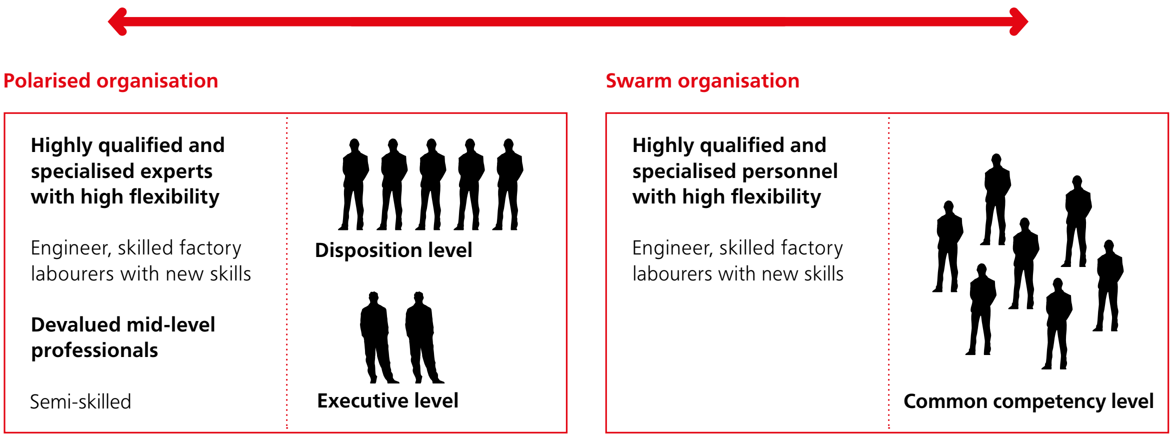
Mid-level employees: ↑

Specialised employees: ↑

Highly qualified: ↑

Source: Ganz 2014.

Figure 8
Polarised versus swarm organisation



Source: Hirsch-Kreinsen 2014: 4.

own working life, both in terms of where and when they do their jobs as well as the nature of the activity and access to the task at hand.

A polarisation of employment is thus assumed to be on the horizon in which certain jobs with mid-level skill requirements and pay will be the first to be made redundant through automation ushered in by Industry 4.0.

Frey and Osborne (2013) go much further in their scenario. They forecast that half of all the jobs in the US labour market could feel the effects. For Germany, this scenario does not seem quite realistic due to the difference in how the production systems and qualification profiles are set up. The consequences could also prove to be less dramatic than in other countries due to demographic change and the impending skilled-worker shortage.

Autor and Acemoglu's polarisation theory (2011) seems more applicable to Germany. Accordingly, vocations at the lower and upper ends of the qualification spectrum that are less automatable and more experience- and interaction-based professions would gain in relevance. This is also where we can expect to see completely new fields arise (Picot/Neuburger 2014). Furthermore, due to increased outsourcing, the droves of "click workers" and "cloud labourers" who are poorly paid and less socially secure as freelancers will most likely grow.

IMPACT ON LABOUR ORGANISATION WITHIN COMPANIES

What does all this mean exactly for the organisation of work? Hirsch-Kreinsen (2014) recommends redesigning the entire socio-technical production system. In the process, no "one-best-way" would establish itself; rather, a whole gamut of differing organisational forms could be implemented in the future. These would lie somewhere on a spectrum between a polarised and a swarm-type organisation (figure 8) or a mix of the two.

Figure 9
Design of human-machine interaction

	Humans employ systems – specialisation scenario	Systems direct humans – automation scenario
Content of work	Interesting customisation of tasks with the possibility of influencing both design and target	Close customisation of tasks with a high degree of standardisation/external control
Organisation of work	Opportunities to expand cooperation with common goals and participation	High level of responsibility with little flexibility
Networking	Controllability of standards and cooperation in a transparent context	Relief from dirty, dull and dangerous activities
Automation	Default to tight standards in case of insufficient transparency in the context of connectivity and knowledge use	The goal of automation: worker-less factories
Qualification / skills	Linking workplace learning with overarching skill development	Exclusively on-the-job training
Data	Access to information and knowledge for problem solving; separation of personal and technological data	Use of data for the control of conduct and performance

Source: following Kurz 2014.

Polarised organisation takes on the tendencies of internal differentiation in terms of tasks, qualifications and personnel occupations. Firstly, this form is appropriate for the needs of a production system that only has very few simple tasks with little or no flexibility. Secondly, it employs a growing number or even a new group of highly qualified experts and technical specialists whose qualifications greatly surpass those of any skilled factory labourer today. These employees are not only expected to stand at the ready to deal with issues that come up (e.g., troubleshooting), but also to take on different production management tasks (Hirsch-Kreinsen 2014).

Swarm organisation is at the other end of the spectrum. This form of work organisation is characterised by a loose network of very well qualified and equally active employees. It no longer comprises simple and low-skilled activities, because these have largely been replaced by automation. There are no defined tasks for individual employees. Instead, the work collective acts in a self-organised, highly flexible way that is determined by the situation at hand. Swarm organisation is a design that relies on the explicit use of informal social processes of communication and cooperation and stresses the related extra-functional competencies as well as the specific process knowledge of the employees (Hirsch-Kreinsen 2014).

In both of these scenarios the human comes back to the centre of things as the – better-informed – decision-maker (see figure 9). At the same time, however, the dependence on data rises even further. For this reason as well, the aspect of data protection, privacy and security gains a special importance. Additionally, the employees should be involved in the (re-)design of work organisation in Industry 4.0 from the very beginning. As co-designers and co-deciders they will, therefore, become central drivers of technological and social innovation.

2.4 WHERE WE STAND TODAY

It is striking that many publications about Industry 4.0 today focus mainly on the Internet of things, smart objects and smart factories. The concept "Industry 4.0" is primarily being explored from a technical point of view. There has been very little inquiry into the question of what it means for people and our society on the whole. Increasing digitisation, however, will not only have an enormous impact on machines, factories and sectors, but on societies as well. That is why we must look more closely at this aspect. Where are the risks – but also where are the opportunities for social innovation and progress?

A social innovation is a novel solution to a societal challenge that is more effective or more efficient, sustainable or more equitable than existing practices. The good of society is in focus rather than the benefits to a single innovator. Therefore, these solutions must come about through a common evolution, developed directly by the beneficiaries in society. A social innovation can take many forms, a principle, law, organisation, behavioural change, business model, product, process or technology. Usually, social innovations result from a combination of these components. Thus from today's perspective, many innovations can be classified as social innovations – from book printing to health insurance, universal suffrage and energy efficiency, fair trade or the Internet – innovative solutions that have brought major societal benefits. Social innovations have the greatest impact on a system-wide level. Hence, technical innovations can very positively influence the diffusion of social innovations. And vice versa, technical innovations often only develop their true potential in combination with a social innovation. Successful business ideas can thus offer both economic benefits as well as social progress. Especially in the context of Industry 4.0, we need to keep this goal in mind at all times. We should ensure that the returns from digitisation are generated by as many people as possible and distributed amongst as many as possible.

3

TEN POINTS REGARDING INNOVATION POLICY FOR INDUSTRY 4.0

Increasing digitisation seems to be leading to immense innovation potential. Technically, through the fusion of goods and services for intelligent objects and products, production can become faster and resource-efficient. Organisationally, new enterprise organisations could lead to new employment forms and business models. Socially, the balance between career and family or old age and disability can find equilibrium (through the deployment of intelligent assistance systems).

These developments also entail enormous risks – at the individual as well as the societal level. Added flexibility may also mean further delimitation of work, acceleration, more intense work with more stress and other new challenges to work-life balance. There are other sensitive areas to keep in mind, such as protection, privacy and security. The potential of these systems for surveillance purposes is also a major question. What does this all mean for innovation policy?

POINT 1 INDUSTRY 4.0 NEEDS THE PROMOTION OF SYSTEMS

Industry 4.0 arises within systems, in the interaction between networks and many different actors. It radiates outward with multiple thematic issues: data privacy, protection and security (safety & security), legal, social and technological standards, business models, organisation of work. Technological innovations stimulate social innovation and vice versa. It is precisely, because new organisational forms arise that new technologies and techniques take shape.

It is the inclusion of operators, suppliers and users that accelerates the innovation process, but also helps standards to be developed.

Some Industry 4.0 products and services will thus be developed as "open innovations". This fact presents new challenges to many German companies, which traditionally tend toward "closed innovation". This is true especially for the manufacturing industry. Here companies often only avail themselves of ideas and technical skills that are available within their own domain or within the network of closely integrated, well known partners.

To survive in the Industry 4.0 world, companies and their personnel have to strengthen their "interaction competence" (Howaldt/Beerheide 2010: 358 et seq.), which refers to skills and abilities of an organisation to successfully implement open innovation. Due to the fact that these processes, innovative products and services are increasingly marked by cross-sector technological integration, Industry 4.0 development demands networked collaboration between differing skill sets and knowledge caches. With growing digitisation, the latter will likely become codified and easily passed on. From this stems the need to combine each party's own competencies with the complementary knowledge and conduct of the others' (Howaldt/Beerheide 2010).

Innovation policy has to take this into account. Policy has the power to support this complex orchestration of various perspectives and disciplines to adapt to and learn from one another better and more quickly. Policy can promote networked thinking, openness and exchange to strengthen companies' "absorptive capacity" (Cohen/Levinthal 1990; Hirsch-Kreinsen 2010) – in schools and universities, in vocational training and further education programs, it can promote active network building. It can stimulate collective learning, also by integrating non-research-intensive enterprises, so that new technologies and new knowledge can diffuse more quickly. Innovation policy can promote the creation of inter-disciplinary project coalitions and competence centres through competitions or initial project funding. It can support the transfer of basic research findings into application development through real-world experiments, living labs and factories that demonstrate these future technologies (e.g., WITTENSTEIN Industrie-Campus; it's OWL).

POINT 2 INDUSTRY 4.0 IS NOT JUST ABOUT HIGH-TECH

High-tech innovations are considered particularly attractive to the science and business communities, policy-makers and society. Paul Romer's model for endogenous growth provides theoretical explanation: the greater the proportion of an economy's labour force involved in research sectors, the stronger that economy's growth. Since its inception, many innovation analyses and innovation-policy approaches have been following this principle all over the world. The formula is then: more is better. That means one can invest as much as possible in research and development (R&D) and supposedly sit back and watch the positive effects on production and the blossoming market. Innovation processes, however, are not linear and seldom develop following a cascade model. While supply-induced innovation processes that are highly technologically driven can be found this way, there are a great many innovations that are rather demand-induced, i.e., meet customer needs, are based on practical knowledge or user experiences. Hence, along with classic promotion of research for technological sciences, one should also focus more on social sciences as well.

Hirsch-Kreinsen (2010) calls attention to the heterogeneous knowledge base of innovations in his research and raises the – often underestimated – significance of practical knowledge in the development of innovations in many industrial branches and enterprises.

Against the backdrop of his critical considerations, he calls for a departure from state innovation policy's "high-tech obsession" and for policy-makers to focus on the specifics of innovation processes in non-research intensive sectors. Industry 4.0 needs both. This is what Industry 4.0 is specifically about: science-based innovation alongside application and customer-induced innovation. That is why we must take a timely look at how to design these socio-technical systems (e.g. polarised organisation versus swarm organisation) and their framework conditions – including as many potential users as possible and the scientific monitoring of these processes.

POINT 3 INDUSTRY 4.0 LEADS TO SOCIAL PROGRESS

Industry 4.0 demands a lot, above all from people. There is a lot of potential in hibernation at the moment, and not just for the highly qualified few. We have to rely more on social innovation so that growing flexibility does not only emphasise the darker side of delimitation of work. Combining easy-to-use technical assistance systems with new social practices as well as better dovetailing of various services could then open the window of possibility for more social progress: participation and social integration, inclusive growth and improved career compatibility with family, caregiving, age and disability needs.

Social innovations occur in dialogue. The dialogue with society must therefore be an organic part of research and innovation; in turn, it can strengthen the technology openness and risk maturity of society. Whoever takes innovation through participation seriously has to do more regarding the framework conditions in addition to the technological developments and their integration into our life-worlds: areas like data protection, privacy and security; copyright, competition regulations and intellectual property rights. This calls for investigative and advisory measures at an early stage in respect to how legal framework parameters should be adapted to new technological developments, social practices and business models. This dialogue also has to be promoted amongst companies. The course of internal dialogue has to cite the specific obligation of company and project management levels to ensure a participatory environment in which employee suggestions and advice can be incorporated. Motivation and promotion through targeted personnel development and the corresponding company culture are not-to-be underestimated stimuli for successful innovation processes. Thus those affected by Industry 4.0 become its co-designers, who can then drive its diffusion process into other societal areas, accelerating it.

POINT 4 INDUSTRY 4.0 SHOULD BE UNDERSTOOD AS SOCIAL INNOVATION

Social innovations have crucial influence on whether a technological invention will become a widespread innovation (Schumpeter's distinction), on the channels it is diffused through and what effects unfold in the process (Franz 2010: 336). A social innovation is a targeted reconfiguration of social practices with the aim of better solving problems or satisfying needs than is possible on the basis of established practices (Howaldt et al. 2008: 65) and thus makes a contribution to social progress.

Better: for whom? In this question lies a further subtext of the definition, namely its normative connotation. According to this understanding, an innovation can only be social when it is socially accepted, widely diffused in society or amongst certain social groups and finally becomes institutionalised or routinised as a new social practice (Howaldt et al. 2008: 65; Zapf 1989: 177). Industry 4.0 still has to prove its benefit to society.

Only when the developments within and around Industry 4.0 actually result in social added value (e.g. Decent work or new labour quality), when social practices that are "better for people" establish themselves – for both consumers and the supply side as well as labourers in the smart factories of the future – can the dual character of social innovation indeed be fulfilled. This can only take place if Industry 4.0 is understood in terms of social innovation as well as being technical, only then will we have answers to the profound upheavals it entails.

POINT 5 INDUSTRY 4.0 SHOULD BE EMBEDDED IN A COORDINATED MARKET ECONOMY

Thanks to comparative analysis of capitalism (e.g. Hall/Soskice 2001), it is accepted in academic circles that the liberal Anglo-American market economy is not the only success model. It has been shown that a coordinated market economy can also thrive, if it concentrates on its strengths (institutional complementarity). This finding appears especially conducive to Industry 4.0. For many years, Germany has been the prototypical coordinated market economy. German companies have counted on long-term, trusting relationships with their employees, suppliers and development partners. German enterprises take advantage of "patient capital" much more than their foreign competitors do and are thus competent in sectors that benefit from incremental innovation (e.g. machine and facility engineering). They coordinate their activities in networks. This "culture of cooperation" is also supported by strong industry associations through sectoral wage negotiation, participation, dual skills training and vocational training opportunities. Policy-makers should attend to and strengthen this culture of cooperation, promote its networks and partnerships and above all provide for the right framework conditions: infrastructure (e.g. expansion of general access high speed broadband networks and transport solutions) and excellence in educational and research institutions.

POINT 6 INDUSTRY 4.0 IS NOT JUST ABOUT MACHINES BUT PEOPLE

The Internet of things, data and services are merging the physical and digital world (Forschungsunion 2013). This is where Internet- and knowledge-based services have a huge task ahead. Knowledge often takes the form of practical knowledge: "learning by doing" and "learning by using". People are the bearers of this knowledge and the drivers of innovation. Thus, the question arises: What kinds of skills do people need for Industry 4.0? And just as important: How can people and society benefit from Industry 4.0?

In regard to the polarisation thesis, people in Industry 4.0 would benefit first and foremost from intuitive operations for the cyber-physical systems. Design becomes the motor of innovation. Moreover, more training, further education and qualification programmes take the fore. We also have to educate people in terms of risk literacy, i.e., trial and error tests, applications and research, taking risks and if necessary failing, but they must also get second chances. In a culture of participative cooperation, lifelong learning should be promoted through personnel training and career advancement – in the academic system as well. However, this also includes: improved funding of universities, improved career chances in academia (perspective, tenure track) to promote the (international) mobility of researchers and inventors and personnel exchanges between academia and business.

POINT 7 INDUSTRY 4.0 NEEDS EUROPE

The European Commission and the European Parliament are trying to bolster Europe's (re)industrialisation with the new research framework programme Horizon 2020. Therefore, it seems advisable to develop system solutions in EU networks, in order to occupy a stronger position at a global level. The EU could evolve into a lead market for Industry 4.0. A lead market is a geographically demarcated market that promotes innovation through favourable local preferences and conditions. Successful providers encounter critical users and differing needs. It is not about reinvention, but about cooperation. Everyone will benefit from the greater number of cases in EU-wide research and application projects, will gather experience, learn from one another and develop common standards – with regard to data privacy, protection and security (e.g., European cloud infrastructures, digital interior markets or European legal frameworks). Industry 4.0 is precisely where two differing standard regimes meet: one from the IT sector that is more greatly influenced by US standards and another regarding machine, facility and vehicle engineering, which is more European. The interesting question is which regime will prevail.

If there is a doubt, one should also look to the sheer size of the market. Europe (still) has a stronger industrial marketplace than the US. There are nearly 800 million inhabitants on the continent – the 28 EU member states make up a population of half a billion. Therefore, Europe should reflect on its strengths – but loose no time in picking up the pace and intensity to establish dominance in the most important areas at an early stage. Economic integration remains one of Europe's major strengths, which is linked directly to the size of the market – a huge advantage when it comes to setting standards. Unfortunately, these opportunities are still neglected far too often, as the economic actors follow their own short-term national interests. Moreover, many EU policies still permit considerable national discretion (Enderlein/Pisani-Ferry 2014: 41 et seq.). This leads to fragmentation and small-time plays that miss the big win. Common standards, norms and rules could make a major contribution to more positive integration and cohesion, and therefore to more growth and social progress.

POINT 8 INDUSTRY 4.0 NEEDS BETTER DATA PRIVACY, PROTECTION AND SECURITY

"Digital data will be the most important raw material in the future" (Forschungsunion 2013). Ensuring data privacy, protection and security in a digital world is thus a central task for German research and innovation policy as well. Security and safety research, however, does not merely involve technological topics. Rather, these represent socio-political concerns, whose meaning extends over all fields of action (Bornemann 2014; Renn 2014), because data safety and privacy starts with people's behaviour. This means taking thoughtful and competent actions regarding one's (own) data and ensuring adherence to technical and legal matters. Thus, the security aspects have to be taken into account during the planning of new products, business models and training modules. An example of this is the "backdoor" issue. Industry 4.0 platforms "generic enablers" must impede espionage of data through backdoors. The German Federal Office for Information Security or a European regulatory authority could certify the respective products and services as backdoor-free – and thereby potentially induce even more technical innovations. Standards and common European rules are needed in these areas: data security in the industry, copyright, privacy protection, the "right to be forgotten" and much more (Enderlein/Pisani-Ferry 2014).

Altogether, policy-makers can collaborate in data privacy, protection and security developments, possibly by introducing financial incentives to companies for developing or procuring security solutions or by setting regulatory norms (e.g., the EU's proposed General Data Protection Regulation). Another area ripe for support is information and education starting in schools.

POINT 9 INDUSTRY 4.0 IS ALSO ABOUT THE SMALL

So far, it has mainly been larger companies that are interested and involved in Industry 4.0. However, 99.6 per cent of companies in Germany are small and medium-sized enterprises (SMEs) (IfM 2014). Strikingly, SMEs invest much less in research and development than big corporations. They also apply for fewer patents and create fewer technological innovations (Maaß/Führmann 2012). Their strengths, however, are cooperation and strong representation in industry, where they are above all involved in modernisation (process innovations). SMEs are both providers and consumers and are crucial for the diffusion of new technologies and practices of Industry 4.0. Thus, these companies could be the leaders in terms of social innovations and deserve the support that larger companies receive under the auspices of the "high-tech obsession".

This beckons the question: How do we get more small and medium-sized enterprises involved? First, an innovation policy could promote the use of ICT – for (in)direct procurement or educational and training opportunities. The cyber-security sector (see point 8 above) seems especially promising when it comes to fuelling demand as well as new offers. In addition, support standardisation seems appropriate. German companies are traditionally very strong here – even global leaders regarding their engagement with ISO and other standards committees. ICT standards, however, are often developed outside of these committees. Thus, the various organisations should carry out intensive standards monitoring. In return, policy-makers could promote cooperation with ICT-relevant standards consortia. Industry 4.0 offers an opportunity here for SMEs from various sectors to come together. Now that sectors where SMEs have traditionally been deeply involved (machining, automotive engineering, etc.) are turning toward ICT implementation, the SMEs are in a key position with their strong associations and networks to transfer these strengths to other sectors (ICT itself and the service industry). This process would be enormously helpful to the setting of standards.

POINT 10 INDUSTRY 4.0 NEEDS POLICY COORDINATION

Systemic innovations, such as Industry 4.0, are characterised by the interplay between technological and social innovation. Thus, the technological and social aspects are coming together and enabling a comprehensive, embedded process of change. This holistic understanding of innovation also requires a broader understanding of innovation policy. Along with this come questions of research funding and knowledge transfer from academia into business, concerning the promotion of modern and participative personnel policy, the efficiency of the science and R&D system, internationalisation, establishment of new business models, research into services, the future organisation of the world of work and social acceptance of new technologies (Forschungsunion 2013).

German innovation policy has traditionally focused on promoting technical innovation, primarily relying on the supply side (so-called technology push). It is time policy-makers concentrate on the demand side and promote the development of social innovation. Only then can good technological ideas prevail in our everyday lives across the board and ensure social progress, e.g., resource sustainability, more qualifications for those who seek further training and "good jobs", and a better work-life balance. A social innovation policy arises when technological innovations (Industry 4.0/digitisation) are accompanied by a systemic policy approach that takes up and integrates important contributions from other policy areas. This requires more coordination – across ministries and beyond policy levels (Buhr 2014). Just as in economical matters, speed is of the essence here. However, the effort should not be everyone scrambling at the same time (the usual competence jockeying) , but rather a coordinated, concerted one that follows a strategy – with the goal of the broadest possible social diffusion of digitisation.

4

CONCLUSION

In the future, companies will network their equipment, storage systems, resources, employees, supplier and partner companies and their customers via socio-technical systems (cyber-physical systems) worldwide. Thus, there is enormous potential behind Industry 4.0: individual customer demands can be taken into account and even one-off, tailored production may become profitable; production will become faster and more flexible; this reduces the resource usage and improves productivity. Employee productivity may very well also greatly improve. Flexible work options could allow for better work-life balance in terms of both time and location. It is conceivable that certain production processes could be shifted (back) to Germany and into urban areas.

Even if the issue has so far been analysed and driven from a purely technical standpoint, people remain an integral part of a decentralised and self-organised Industry 4.0. Labour and the workplace, however, will change a great deal in many areas. Tasks will become more complex and the value creation networks more dynamic. This requires a high degree of flexibility. New learning tools are in demand: assistance systems, robots, e-learning.

Industry 4.0 calls for more know-how gained from experience and networked thinking. Machines work well for standardised production and will be there to assist people in preparing and making better decisions. In other words, people ask better questions – and machines should help them giving better answers. Machine design (e.g., intuitive operation) and both internal and external communication thus gain in importance.

This is how Industry 4.0 will be able to maximise its potential for digital innovations, new services and business models. This could mean major opportunities for start-ups and entrepreneurs – perhaps the form of enterprise that best describes the advantage that humans have over machines (Bertelsmann Stiftung 2014: 6).

What role does innovation policy play? Many. According to an Industry 4.0 index survey, three quarters of the respondent companies lack relevant political support (Staufen 2014: 11). Thus, it is time to act. Policy-makers should encourage both technical and social innovation, taking all the possibilities into account on the supply side, but on the demand side as well. A systemic understanding of innovation policy is required; one that includes strategy and coordinated implementation so that technical innovations become societal ones and important contributions to social progress can be made.

Several concrete tasks thus call for political action: Stimulating collective learning – also by integrating non-research-intensive enterprises – so that new technologies and new knowledge can diffuse faster. Innovation policy should promote interdisciplinary project coalitions and competence centres through competitions or initial project funding. It should support the transfer of basic research findings into application development through real-world laboratories, living labs and factories that demonstrate these future technologies. This, in turn, encourages communication and cooperation and prepares the ground for social and technical innovations. The demands are mainly in the areas of data privacy, protection and security. In regards to supply and demand in this area, innovation policy could support (in)direct procurement, development of secure infrastructure, vocational training and qualification opportunities. Moreover, Europe itself must be understood as an opportunity for Industry 4.0. As a lead market, it has the potential to set standards worldwide, for data privacy, protection and security (e.g., European cloud infrastructures, digital interior markets or European legal frameworks).

Industry 4.0 still has to prove its benefit to society. Only when the developments within and around Industry 4.0 result in social added value, when new technologies, regulations, services and organisations establish themselves in the society and when these social practices prove to be “better for people”, will we have recognised and put the potential for Industry 4.0 to work. On the path toward these goals, coordinated speed and active policy are needed – policy that promotes and demands, that sets clear rules, but also invests in the future.

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List of Abbreviations

BDI	Bundesverband der deutschen Industrie (Federation of German Industries)
BITKOM	Bundesverband der digitalen Wirtschaft (Federal Association for Information Technology, Telecommunications and New Media)
BMAS	Bundesministerium für Arbeit und Soziales (Federal Ministry for Labour and Social Affairs
BMBF	Bundesministerium für Bildung und Forschung (Federal Ministry of Education and Research)
BMBFSFJ	Bundesministerium für Familien, Senioren, Frauen und Jugend (Federal Ministry of Family Affairs, Senior Citizens, Women and Youth)
BMG	Bundesministerium für Gesundheit (Federal Ministry for Health)
BMI	Bundesministerium des Innern (Federal Ministry of the Interior)
BMVI	Bundesministerium für Verkehr und Digitale Infrastruktur (Federal Ministry of Transport and Digital Infrastructure)
BMWi	Bundesministerium für Wirtschaft und Energie (Federal Ministry for Economic Affairs and Energy)
CPS	Cyber-physical system
HTO approach	Holistic technical organisational analysis approach that takes especially people into account
ICT	Information and communication technology
IP	Internet protocol (network protocol, the foundation of the Internet; it enables computers in large networks to be addressed and sent as IP packets)
IT	Information technology
ITC	Information & telecommunications technology
ISO	International Standards Organisation
RFID	Radio-frequency identification (identification by using electromagnetic waves)
QR codes	Quick response codes (graphical method for encoding information for high-speed machine readability)
R&D	Research and development
SME	Small- and medium-sized enterprise
TC	Telecommunications technology

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