Hamburg Institute
of International
Economics

THE DIGITAL ECONOMY

Strategy 2030

Wealth and life
in the next Generation.
An initiative of
the Hamburg Institute of
International Economics
and Berenberg

BERENBERG
PARTNERSHIP SINCE 1590

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HWWI

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**»The world is facing massive upheavals. [...]
The irony is that people who tried to predict the downfall brought about by automation were always wrong.«**

ROBERT SHILLER, NOBEL PRIZE-WINNING ECONOMIST

Strategy 2030 is the title of a research series that our Bank has been publishing since 2005, together with the Hamburg Institute of International Economics (HWWI). Our aim with these studies is to highlight trends that we are engaged with today which will also have an impact on tomorrow. After all, our behaviour today will definitively determine and influence the lives of the next generation.

The world is changing at an increasing pace. This pace is being driven by the increasing frequency of new technological innovations, a rapidly expanding body of knowledge, and a globalised economy. Political, social, technological and economic catalysts have become fully integrated in this process of transformation, sometimes magnifying each other's effects, sometimes hampering further progress. As a result, these changes are perceived as becoming ever more complex and increasingly less tangible. This point is gaining increasing relevance, as the developments that are taking place now will inevitably affect matters far into the future, resonating across generations.

In light of this, we are dedicating the »Strategy 2030 – Wealth and life in the next generation« series to long-term, macroeconomic questions which go beyond traditional themes related to financial markets, focusing on social processes of transformation. The studies combine the expertise of economic researchers who are renowned beyond our nation's borders with the comprehensive experiences of a leading private bank that is steeped in tradition.

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Executive summary

- The German economy is humming. Tax receipts are pouring in, the labour market is booming, and Germany was and has remained solid as a rock during the euro crisis. That is the current situation. But is Germany also prepared for the digital revolution?
- A core element of Germany industry (the »German business model«) is its ability to adapt quickly and comprehensively to global structural change. Digitisation currently represents a new megatrend. With its strong industry, efficient small, mid-sized and large companies, closed value chains and consistent orientation towards global markets and innovation, the German economy is fundamentally well-prepared for digital change.
- At the same time, there are a whole host of serious weaknesses in Germany as a location of industry which, if they are not addressed promptly, could lead to the German economy missing the digitisation boat. These include things like arrears in the digital infrastructure and deficits in software development.
- Digitisation is changing business and society from the inside out. People are already starting to talk about the next industrial revolution dubbed »Industry 4.0«. Following on from automation, the decentralisation of production is now taking place with the interconnection of machines.
- Is our economic system hanging in the balance? A huge decline in marginal costs (zero-marginal-cost society) in many areas of production is an important feature of the digital economy. The consequence could be excess instead of scarcity. Furthermore, a change in culture is becoming apparent: ownership is losing ground while usage opportunities are gaining in significance (the »sharing economy«). This is giving rise to speculation about alternative economic models (»the end of capitalism?«). The world after the digital revolution will, however, not be an economic paradise. Scarcity issues remain on the agenda.
- Thanks to digital technologies, there are a multitude of new business models that are fundamentally altering existing markets and putting old business models under pressure. The economic effect of digitisation thus goes well beyond usual efficiency gains (from falling transaction costs, for instance).
- Are we running out of work? Will jobs fall victim to technological progress? There was already a fear that technology would trigger unemployment during the course of past industrial revolutions. In terms of at least lasting and nationwide impact, however, this has not happened to date. That said, the increasing ability of computers to learn (by analysing big data) means that activities with higher skills profiles are also coming under pressure. The risk of technological unemployment as Industry 4.0 takes hold cannot be dismissed out of hand.
- In a scenario calculation, we put the additional potential for value creation from Industry 4.0 at €17–25 billion a year through 2030. What is certain is constant change, which will probably take place with increasing speed.

- 3D printing is a technology that boasts huge growth potential within the framework of digitisation. Digital printing instructions enable the local production of goods like semi-finished products, and capital and consumer goods. Should 3D printing become faster and cheaper, the technology contains the potential for economic disruption as well as opportunities for the German export industry.
- Digital change is bringing a new dynamic to the automotive industry and the mobility market. Designing traffic networks, offering sharing models and guaranteeing sophisticated digital features are key aspects of sustainability in the mobility sector.
- The financial sector will not be left unscathed by digitisation either. Alongside payments and lending, fields like portfolio management are among the top candidates for feeling the pressure from what is known as FinTechs. These firms will help to enhance existing financial services and roll out completely new offerings. In the long run, though, solutions are also likely to become established solely because they are considered modern and contemporary, even if they yield very few or no advantages compared with what already exists. We expect this phenomenon to apply across the board and not just in the financial sector.
- The challenges that arise for economic policy will depend upon whether the digitisation process turns out to be merely another episode of far-reaching structural change (this is our main scenario). In this case, economic policy would primarily need to keep the markets open in order to facilitate dynamic change. Moreover, economic policy would need to cushion social aspects of the transition from analogue to digital economy.
- Should huge numbers of old jobs be lost as a result of the digital revolution, however, without new jobs being created in anything like the same numbers (our risk scenario), it would be necessary to completely rethink parts of economic policy. If workers have no realistic chance of finding employment any more, no matter how willing they are to learn and adapt, because the work is done for the most part by computers and robots, social policy above all would be called upon to tackle the ensuing equality problems.

1 Introduction

Digitisation is by no means a completely new phenomenon. By the time of the dotcom boom of the late 1990s at the latest, it was clear that the economy was facing a massive upheaval. A good decade and a half later, internet corporations are already established players in the corporate world. If the topic of digitisation is still omnipresent in 2015, making headlines in the business press under the catchphrase »Industry 4.0« day after day, there are good reasons for this. Previous experience with the digital revolution – as seen in the music industry and the media landscape, for instance – provides a foretaste of what many other industries might be about to undergo. Big data, connectivity and artificial intelligence are the buzzwords that stand for the next round of the digital revolution and underpin the concept of the digital economy.

Today, it is not just the multitude of innovations that astounds but also the speed with which business and society are being turned inside out. The fast pace of change can largely be explained by the fact that markets are being created in the digital economy that operate in line with the »winner takes it all« principle. This means that speed is a key success factor for enterpreneuers and enterprises, as the prospect of global market domination is dangled. That such potential success is triggering something of a gold-rush mood comes as no great surprise. At the same time, though, both established companies and workers who fear for their jobs are becoming increasingly nervous.

With this study, we hope to contribute to a better understanding of this digital upheaval and provide an insight into the prospective changes that can be expected in business and society. In section 2, we describe the underlying concepts and special features of the digital economy. We then focus on four selected topics with a view to pinpointing the economic consequences of digitisation. First, we outline the German business model (section 3) and consider whether the current structure of the German economy forms a good foundation for mastering the challenges of the digital revolution. In section 4, we use the example of 3D printing to examine the potential of digital technologies to disrupt economies. We then go on in section 5 to use the automotive sector to explore the possible consequences for one of Germany's key industries. In section 6, we highlight the consequences of digitisation for the financial sector. Finally, in section 7 we draw up implications for economic policy and examine whether the market economy is in any position to channel the peculiarities of the digital economy in such a way that the newly created prosperity benefits all social groups and not just a digital elite.

2 Fundamentals of the digital economy

2.1 The economy facing digital change

Digitisation has triggered massive structural changes across the economy and society. The value-creation processes in business and the patterns of consumer behaviour among people are being determined by digital technologies to an ever greater extent. Today, computers are employed in just about every field of economic activity. Industrial production in Germany is largely automated, and hardly any economic transactions take place without a digital process. Furthermore, digital interconnection over the internet has brought companies and people closer together throughout the world, thus helping to accelerate the process of globalisation.

The cornerstone for digitisation was laid as early as the middle of the 20th century when the transistor was invented. But it was not until the mass usage of computers starting in the 1970s triggered such an upheaval in economic structures that people began talking of a (third) industrial revolution. This quantum jump called a digital, or possibly electronic, revolution resulted in the automation of production together with wide-reaching changes to workflows in both the manufacturing and services sectors. Private households and hence patterns of consumer behaviour were also increasingly affected by digital technologies with the spread of the personal computer (PC) commencing at the start of the 1980s. The next stage of digitisation entailed increasing interconnection by means of the internet. The internet was made publicly accessible for the first time in 1991. Following a niche existence at first, the number of users expanded rapidly. Today, around 40 percent of the world's population are already internet users (for details see Figure 1). At over 80 percent, the share of internet users in the population as a whole in Germany is the same as in most leading industrialised nations (see Figure 2).

Digitisation is, however, by no means concluded. Instead, the next stage can be expected to follow. The associated changes in economic activity are considered so massive by many experts that people are already starting to talk about the next (fourth) industrial revolution under the catchphrase »Industry 4.0«. After the third industrial revolution, which essentially entailed the auto-

Number of internet users worldwide, 1997–2014
millions

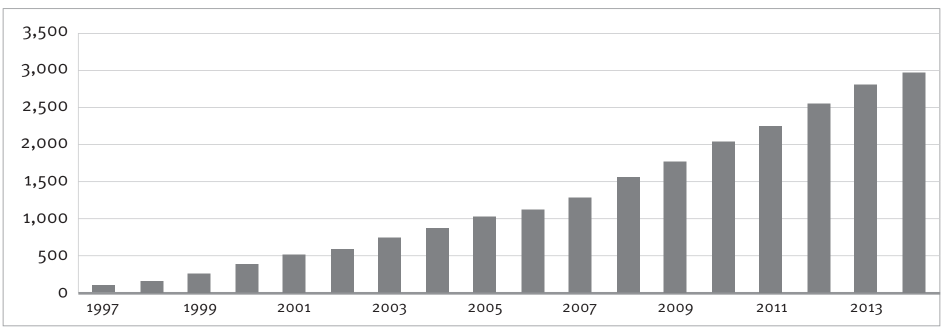

Fig. 1 Sources: Internet Live Stats (2014a); HWWI.

Proportion of internet users in total population of selected countries, 2014

in %

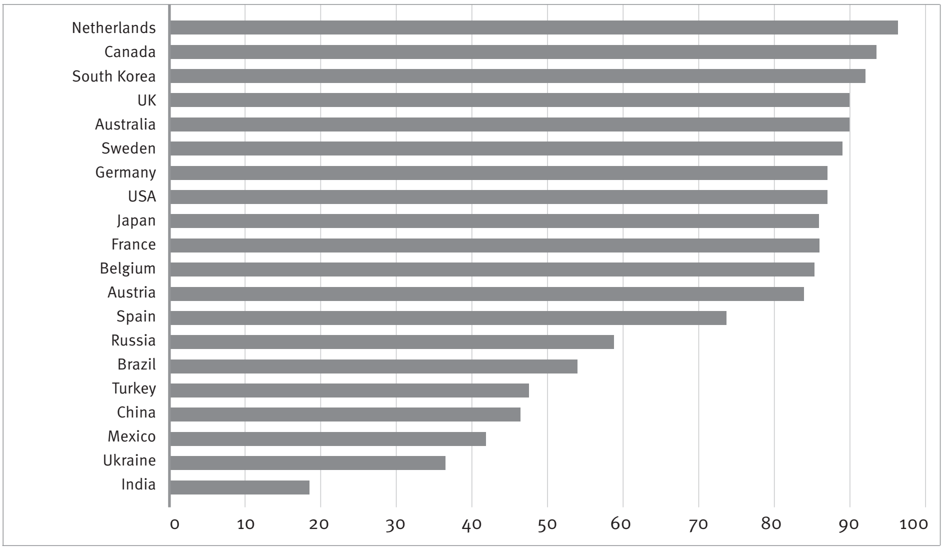

Fig. 2 Sources: Internet Live Stats (2014b); HWWI.

mation of industrial production, the second radical upheaval is now predicted in industrial value creation based on digital technologies. Two key elements are machine-to-machine (M2M) communication and the intelligent evaluation of large volumes of data (big data). These facilitate the decentralisation of the value-creation processes, with smart connected machines acting autonomously.

At present, it is not possible to predict just how diverse the new business models emerging from the new technical possibilities will be in the future. It is very probable, however, that new, digital business models will change markets and put old business models under pressure. A number of current trends suggest that market structures and the relevant competitive situation can change relatively quickly. Thus, new applications for digital technology are making it increasingly possible for companies from other sectors to enter markets and alter the established structures. The upheaval experienced by the music and media industry from the arrival of downloads, streaming and user-made content is just one of many current examples.

All in all, the nature of the digital economy is one of constant change that is affecting almost all walks of life with increasing speed: employment and the value-creation processes in industry and services, the competitive situation in individual markets and patterns of consumer behaviour. It is safe to assume that digitisation will lead to wide-reaching structural changes and marketplace shifts in economies over the coming years. This may be reflected in a fragmentation of value chains, higher shares of value added for information and communications technology (ICT) and new, frequently software- or data-based business models. As a consequence, many new market participants could enter existing markets and put old business models under pressure. At the same time, market concentration will rise dramatically in some areas on account of platform-oriented business models or large ICT firms that set standards. ICT firms will presumably extend their operations more across industry lines. The proportions of value creation accounted for by ICT and services will in all probability rise. All in all, correlations between different industries will increase and traditional market borders will gradually disappear.

2.2 New business models and creative destruction

Digital networking is bringing market participants from various parts of the world closer together and leading to a decline in the information and transaction costs related to the exchange of goods and services. In this context, the economic impact of digitisation goes well beyond possible efficiency gains, falling transaction costs, greater flexibility and shorter response times from the players. Digital technologies create the right technical conditions for a series of new business models that can fundamentally alter the structure and competitive situation of existing markets and put old business models under pressure. This process of innovation – also known as creative destruction as defined by Schumpeter[1] – is happening with ever greater speed as digitisation takes hold. In this regard, the time when the new technical development appears does not necessarily mark the start of a market-changing process. A given technology does not achieve the breakthrough until it is employed in an appropriate business model.

Where this results in existing technologies and business models being superseded, the process is, according to Christensen, also known as disruptive innovation.[2] In many cases, a new combination of production factors based on already existing technologies suffices to trigger an innovation process. As a general rule, the previous area of application for the technology is limited in this context to other industries or specific market niches. The unexpected use of a technology in a new business model can, given fast market penetration, soon put even previous market leaders under pressure, even if they were successful, innovative and well-run companies until now. The introduction of multi-touch user interfaces in smartphones by the new entrant Apple is a good recent example of disruptive innovation. The new technology triggered a boom in sales of smartphones. Nokia, the undisputed global market leader when the iPhone was launched in 2007, was almost completely squeezed out of the market in just a few years (Figure 3). A similar example is Kodak, a company that enjoyed huge success for a long time but which underestimated the speed with which digital photography would conquer the mass market. The old-established firm was much slower to react to the new trend than its big competitor, Fujifilm, and was forced to file for bankruptcy in 2012 after 130 years of existence.

1 Cf. Schumpeter (1912).
2 Cf. Christensen (1997).

Worldwide sales of smartphones broken down by manufacturer, 2007–2014

millions of units

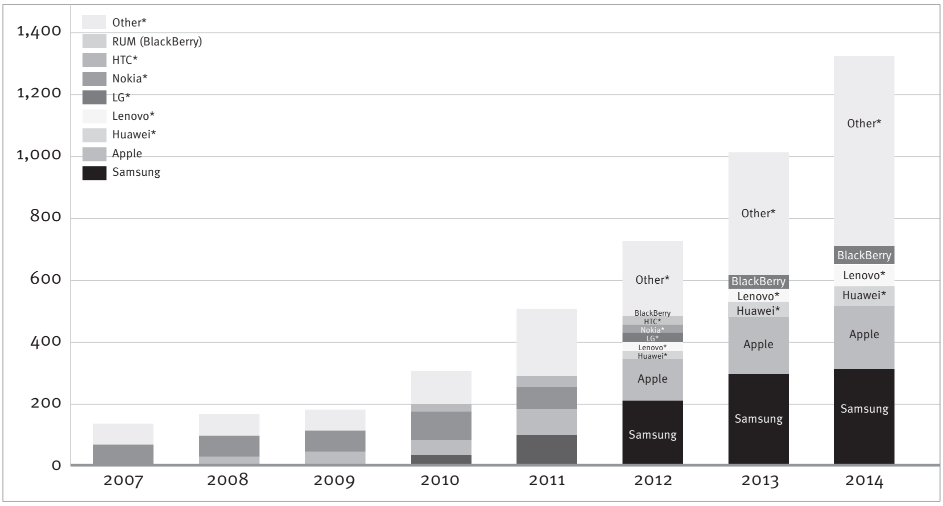

Fig. 3 * The source does not provide information about sales in all the years. The data for 2007 are based on information from Gartner. The source does not provide information about Samsung's sales in 2007. The figures for 2008 and after are based in informatin from IDC.

Sources: IDC (2015); HWWI.

To an increasing extent, digitisation is penetrating every single industry. Thus it is probable that this process will entail further crossovers from the environment of the internet economy and other ICT firms into markets in other sectors. For example, it is becoming apparent that companies like Google and Apple are stepping up their activities in the mobility sector, where digital technologies and network systems are becoming ever more significant for value creation. It is quite conceivable that the existing market conditions will shift in favour of these new competitors from previously different sectors in the course of the imminent sea change in the automotive industry.[3] But it is not just in industry that products and manufacturing processes are changing during the course of digitisation. The use of digital technologies is also giving rise to new business fields in the services sector. This trend is already particularly clear to observe in the retail segment, where e-commerce is placing store-based retailing under increasing pressure.[4]

3 Possible changes in the mobility sector and their significance for the automotive industry are discussed in detail in section 5.

4 Cf. Growitsch et al. (2015).

2.3 The sharing economy and zero marginal costs

The ability to connect many market participants over the internet with low transaction costs opens up new possibilities for alternative market forms and patterns of consumption. The internet is thus breathing new life into what is known as the sharing economy.[5] The concept of the sharing economy is based on the idea that individual consumers do not use many goods in full or do so for only part of the time. In such instances, the shared usage of these goods goes hand in hand with a welfare-boosting effect for the market participants. Consequently, common ownership and the sharing of goods would benefit all.[6]

Up until now, common ownership has only proved its worth in specific cases, such as the use of combine harvesters or similarly expensive equipment in agriculture. The sharing economy is still considered only a side-show overall. According to a survey conducted by the GfK research institute, the most frequently used offers in the sharing economy in Germany at present are: chauffeur services (like Uber), car-sharing (like DriveNow, Car2Go, Flinkster), accommodation offerings (like Airbnb), hospitality networks (like Couchsurfing) and lending platforms (like LeihDirWas). The sharing economy could, however, establish itself in various consumer markets thanks to digital networking. Thus, investment in start-ups in the sharing economy has risen enormously since 2010 (Figure 4). The online agencies Uber and Airbnb in particular have led to a sharp increase in investment of late. According to the Wall Street Journal,[7] the two companies are among the ten most valuable start-ups in the world. Car-sharing has also received new impetus thanks to the methods of mobile positioning and reservation. It is mainly in big cities that driving a car could

5 Also known as »co-consumption«, derived from collaborative consumption.
6 Cf. Weitzman (1984).
7 Wall Street Journal Online (2015).

Worldwide investment in start-ups in the sharing economy, 2010–2014

$ billions

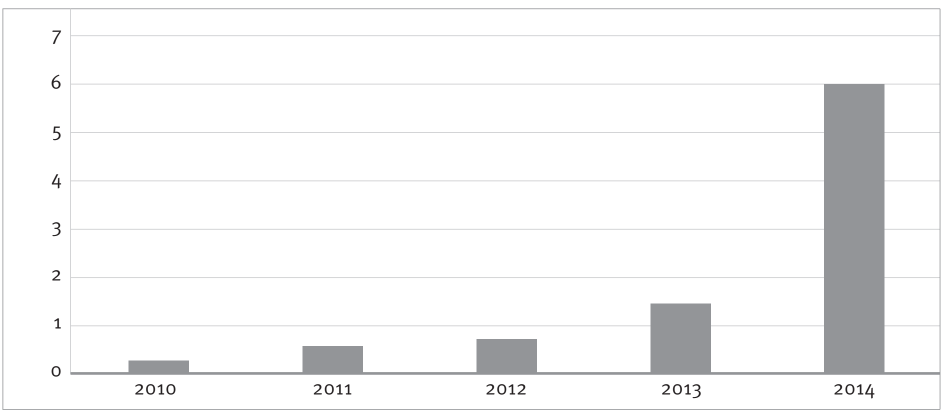

Fig. 4 Sources: Deloitte; Statista.

become more significant as a service that is used occasionally rather than owning a car in the future.[8] It is possible to argue, however, that many areas of the sharing economy are increasingly moving away their original concept. The idea of sharing something that is not needed has, in many cases, evolved into a lucrative business model: Sharing often takes place not because the asset is not needed but because there is money to be made. Thus, people move out of their own homes temporarily for tourists or business travellers because the income from a short-term let is much higher than their usual rent. Or car-pooling becomes a professional chauffeur service that competes with conventional taxi services.

As far as Jeremy Rifkin is concerned, the successful start-ups in the sharing economy are one of the precursors of a decentrally organised economic system based on common property, barter and self-administration.[9] Consumers are themselves increasingly becoming producers. Practically free global interconnections, communications, and the collection and exchange of data are driving the marginal costs for products towards zero. This means that each additional unit of a given good can be produced without additional production costs. Consequently, the corresponding goods would be available in unlimited quantities. Without scarcity, however, the underlying assumption for market-economy activity no longer exists. Rifkin believes that the market economy will be superseded as the predominant organisation arrangement as a result. In actual fact, many services are already offered free of charge on the internet today. Production processes carried out almost fully autonomously by machines seem conceivable in many areas looking ahead. And the concept of the consumer as producer is also not completely absurd, thanks to technologies like 3D printing.[10] However, fully automated, digitised production requires high upfront investment. So there need to be people who make such capital available, although they will expect to make a profit in return. Furthermore, raw materials and other natural resources are not available in unlimited quantities, meaning that production will continue to be shaped by scarcity going forward. Given all this, the full replacement of the market economy as economic form is not on the horizon at present. Nonetheless, a large increase in the relative importance of capital as a factor of production could make it necessary to consider alternative distribution mechanisms between people with and people without capital assets.

8 Possible changes in patterns of consumer behaviour in the mobility sector are discussed in detail in section 5.
9 Cf. Rifkin (2014).
10 Cf. section 4.

Market shares of internet platforms in the field of social networks, search engines and online traders in Germany

Social networks		Search engines		Online traders	
Facebook	36.8 %	Google	91.2 %	amazon.de	29.5 %
Blogger	9.9 %	Bing	3.5 %	otto.de	9.6 %
Google+	6.7 %	Yahoo	1.4 %	zalando.de	3.6 %
WordPress.com	6.7 %	T-Online	1.0 %	notebooksbilliger.de	2.5 %
Stayfriends	4.4 %	Ask.com	0.5 %	bonprix.de	2.1 %
Rest	35.5 %	Rest	2.4 %	Rest	52.7 %

Tab. 1 * Statistics relate to the number of unique users in Germany in February 2014
** Market shares based on revenues in Germany in 2014.

Sources: BML (2015); SEO-united (2015); EHI Retail Institute (2014); HWWI.

2.4 Network effects and multilateral platforms

One key characteristic of digitisation is the interconnection of market participants. Digital networking brings the market participants closer together and leads to a fall in the information and transaction costs associated with the exchange of information, data, and goods and services. Internet platforms such as search engines, social networks and platforms for e-commerce play a key role in this regard. These platforms generally demonstrate the characteristics of an economic network. The underlying quality of an economic network consists of the benefit rising for each and every participant as the network increases in size. This network effect leads to the operators of online platforms targeting global market leadership in their segment along the lines of a »winner takes all« mentality, enabling global monopolies to form. This is demonstrated by the examples of Google, Facebook and Amazon, which are the clear market leaders in their respective segments (Table 1).

As a general rule, such dominant market positions make it possible to extract monopoly rents to the detriment of consumers. This is not necessarily true in the case of internet platforms, however, as they frequently represent networks with two or more market sides. A bilateral or multilateral market is characterised by various market sides generating a benefit from using the platform. Besides consumers, players like advertisers represent a further market side in search engines or social networks, for instance. In portals for online shops, the various vendors form another group of market participants alongside the buyers. In these cases, a platform provider can demand different prices from several market sides for the use of the platform.[11]

In multilateral markets, however, the consumer side is frequently subsidised by the other market participants on account of the positive network effect. For example, strong traffic on a platform has a positive impact on its advertising value or, in the case of e-commerce, makes it more attractive for sellers. In order to maintain or expand its share, the platform provider has an incentive to extract producer rents instead of consumer rents. Consequently, multilateral platforms are often free of charge for consumers to use. Given the beneficial network effects and further econ-

11 The theoretical principles for the analysis of multilateral markets were drawn up by Rochet/Tirole (2003), among others.

omies of scale in the provision of the service, market concentrations can even have a positive impact on consumer rents in the case of multilateral platforms.

A clear correlation between market concentration and welfare effects on multilateral platforms is, however, not evident. Whether market power[12] over the users or other market participants, and associated welfare losses, is present or arises depends on various other factors. The formation of market power is promoted, for instance, if the cost of changing provider to a different network is relatively high (lock-in effect). The bundling of various offers can also play a role in this (exploitation of market power). This is especially possible when a company like Google is active in various markets that address the same user group. On the other hand, a diverse set of user preferences, low barriers to entry and fast-moving innovation and growth on the market concerned serve to reduce market power. These make it possible for competitors to enter the market from outside and trigger a disruptive innovation process.

The collection and evaluation of user data on internet platforms is also of great economic significance. The exclusive ownership of a large volume of such data can turn into a decisive competitive advantage. It facilitates targeted, personalised advertising and the development and/or adaptation of appropriate products or services. In principle, using the data can lead to welfare gains. Optimisation in the development and provision of offers may lead to lower prices, for instance. Furthermore, personalised offers can generate benefits for the consumer. But welfare losses can also accrue if the user is not adequately informed about how his data is employed and it is used to set different prices to the user's disadvantage, as may happen with individual insurance rates, for instance.

All in all, the increasing economic significance of internet platforms with several market sides represents a challenge for competition policy. It is a far more complex task than is the case with unilateral markets to determine whether and under what circumstances welfare losses arise on account of market-dominating positions enjoyed by individual platforms.[13]

12 Market power exists when a company can act largely independent of other market participants (when setting prices, for instance).
13 The importance for competition policy and the special features of multilateral markets on the internet are discussed in detail in a special report by the German Monopolies Commission (2015). For competition-policy aspects of the digital economy, see also section 7 of the present study.

2.5 Industry 4.0

A fundamental reorganisation of production processes is occurring as digitisation takes hold. Following on from automation, the decentralisation of production is now taking place built around the connection of autonomously interacting machines. This is based on not only the collection but also primarily the intelligent processing and usage of the data generated at every stage. Plants are being turned into what are known as smart factories as a result of the increasing digitisation, the connection of all elements involved in the value-creation process, and the systematic evaluation of big data across the entire production cycle and lifecycle of a given product. Machines and product parts communicate with each other autonomously in what is known as the »internet of things« and through cyber-physical systems. This enables production to be planned locally, making it much more flexible and responsive.

Such systems optimise and control the production flows, sourcing activities and logistics processes automatically by analysing collected real-time data. Processes are gradually made more efficient as a result of the collation of data across the entire process and intelligent evaluation by learning machines and systems. Massive time and cost savings are expected as a consequence. Depending on the industry and method of analysis used, the estimates of the possible efficiency gain from Industry 4.0 in various studies vary from 2.5 to 8 percent.[14]

Greater flexibilisation is making production in smaller lot sizes more cost-efficient and the ability to individualise products is increasing. The customer and his specific wishes are taking centre stage. Alongside more individual products, new services are also playing a major role. The main feature in this context concerns downstream digital services, known as smart services, that relate to the process of using products. After-sales services, like maintenance and advice, and product-related services that may complement the product and its usage are becoming more important. In general, the focus will shift from offering solely products to offering integrated value-added solutions. Instead of a product being bought, the use of the product could be offered as a service, including repair and maintenance alongside provision of the product. The collection and evaluation of data across the entire lifecycle of a given product – including during its usage – is making products and related services ever more specific and more valuable over the course of time.

All in all, the changes taking place as part of Industry 4.0 go well beyond industrial production. Many service activities are closely linked with industrial value creation. Logistics, for example, plays a key role in the value chain. In order to optimise both inventories and value chains, the requirements for logistics are rising. Real-time information and optimised storage concepts integrated with transport logistics are set to play an increasingly important role. And end users are also being integrated more in the value chain, with smart-home and mobile applications connecting them more closely with companies. Customer-specific products, services and value-added solutions are taking centre stage.

14 McKinsey & Company (2013): 2.5–5 percent, Strategy & PWC (2014): 3.3 percent, acatech (2015): 6–8 percent.

A broad roll-out of the fourth industrial revolution would generate numerous growth opportunities for economies, but also risks. Whatever else, the transformation is giving rise to far-reaching changes in the way business is done. Many technologies associated with Industry 4.0 may have a disruptive effect on existing technologies and processes. The emergence of new business models may lead to a shift in industry borders, economic structures and comparative advantages between countries. Accordingly, it is evident that this development will create winners and losers. Thus, large ICT firms could gain ever more market power, for instance, whereas established mid-sized firms in manufacturing industry or retailing will come under huge pressure to adapt.

All in all, the future economic opportunities and risks associated with Industry 4.0 are hard to assess. Previous study results regarding the potential are unreliable and also often hard to compare, as the potential stated varies with the underlying definitions and hence the effects included. A comparison in a study by the German Federal Ministry for Economic Affairs and Energy (BMWi) showed that a majority of the studies put the annual economic potential in a range of €20–30 billion.[15] According to the BMWi, however, network effects are often not adequately reflected by widespread implementation. These effects could further increase the aggregated potential.

Alongside the possible value-creation effects from efficiency gains and new business models, it is also important to consider what impact the deployment of technology as part of Industry 4.0 will have on employment. Basically, technological change may have both a positive and a negative impact on employment. On the one hand, the productivity gains achieved by the use of digital technologies may help to secure jobs and boost consumer demand with additional income (compensation effect). At the same time, the use of new production technologies and processes may also destroy jobs (redundancy effects). There are concerns that the redundancy effect from Industry 4.0 will predominate in the long run, leading to what is known as technological unemployment. There was also a fear that technology would trigger unemployment in Germany in the course of past industrial revolutions. In terms at least of lasting and nationwide impact, however, this has not happened to date. Nonetheless, shifts have taken place in the fields of activity and the associated demands placed on workers. For example, the demand for labour for standardised activities with low cognitive requirements has declined as automation has progressed. In return, new jobs with low levels of standardisation and greater cognitive requirements have been created.[16]

Building on the growing ability of computers to learn by evaluating big data, however, machines will be used increasingly to carry out less standardised activities on the cognitive side. To cite one example, the intelligent analysis of masses of text and communications data is making text translation programs better and better. Thus, a simultaneous translation app, which contains both language recognition and translation program at the same time, is today not far away from market-readiness. Should the technology also penetrate the cognitive domain of value creation, though, the risk of technological unemployment triggered by Industry 4.0 cannot be dismissed out of hand.

15 Cf. BMWi (2015); Strategy & PWC (2014): €30 billion, BITKOM/Fraunhofer IAO (2014): €28 billion, Roland Berger (2014): at least €20 billion, McKinsey & Company (2013): €145 billion.

16 Cf. Autor et al. (2003).

Scenarios for the development of value creation and employment in Germany through 2030

	Trend scenario	Scenario 1	Scenario 2
Annual value-creation potential (€ billions) (2010 prices)	0.0	24.7	17.3
Gross value-creation growth (%)	19.0	35.1	30.2
Employment growth (%)	-5.3	-5.3	-10.4

Tab. 2

Source: HWWI calculations (2015).

According to an analysis of the US labour market by Frey and Osborne, around 47 percent of the activities currently performed will in all probability be carried out by machines in the future.[17] The aggregate impact on employment does, however, depend upon the actual reach of these redundancy effects and the extent to which new activities emerge (compensation effects). It is, however, hard to make a prediction at present regarding the relative size of these opposing effects. What is relatively certain, however, is that the job profiles at many workplaces are set to change. This means that major conversion and adaptation measures will also be necessary in the fields of education and staff development.

A scenario calculation carried out by HWWI puts the additional value-creation potential from Industry 4.0 at around €25 billion in Scenario 1 and €17 billion in Scenario 2 each year through 2030 (Table 2). This potential arises from the difference from a trend variant that represents the result of a trend projection without additional technological effects under a macro-economic equilibrium model.[18] Earlier estimates for the period from 1995 to 2007 indicated that ICT contributed around 0.5 percentage points to the average annual growth rate of productivity in Germany.[19] Scenario 1 is based on the assumption that the positive effect of ICT on productivity development will double. An additional growth effect of 0.5 percentage points each year is assumed in the first variant accordingly. Comparable productivity effects from ICT were already identified in Belgium, Denmark and the United States in the past.[20] Furthermore, it is assumed that no technological unemployment occurs. The employment trend thus corresponds to the trend scenario, with employment falling by around 5 percent mainly due to demographic reasons. In Scenario 2, it is assumed that employment will fall by a further five percentage points due to technology.[21] In other words, the redundancy effects cannot be fully offset. This causes the additional value-creation effects induced by earned income to decline, meaning that the value-creation potential from Industry 4.0 is less than in Scenario 1.

17 Cf. Frey/Osborne (2013).
18 These calculations were carried out by the HWWI with the aid of the Global Economic Model of Oxford Economics.
19 Cf. Timmer et al. (2011).
20 Cf. ebenda.
21 The net effect of technological change under Industry 4.0 on the demand for labour is impossible to predict. This assumption was made freely accordingly.

Industrial revolutions

During the course of its history, the world of industry has experienced several major upheavals, with which radical and lasting changes in economic and social conditions were connected at the same time. These periods of vastly accelerated gains in efficiency and productivity are normally associated with specific technological innovations and are termed industrial revolutions. A popular division into a first, second and third industrial revolution is not undisputed in terms of economic and social history; the temporal and regional placement is not as clearly delineated as the terminology suggests. Nonetheless, such a view does usefully arrange and clarify the observed characteristics of periods of radical upheaval in industry and society.

In line with this division, the ***first industrial revolution*** dates from the second half of the 18th century until well into the 19th century. The start is normally associated with the invention of the first mechanical production equipment (such as the mechanical weaving loom in 1785), which marked the beginning of the »machine age«. This similarly represents the starting point of the transition from an agrarian to an industrial society. The main technical feature is the use of water and steam power by (steam-driven) machines, leading to the increasing mechanisation of what was previously done by hand. During the course of the first industrial revolution, further machine tools increased the productivity of a worker many times over in numerous areas; transport also experienced enormous efficiency gains from mechanised engines.

In terms of economic history, the ***second industrial revolution*** encompasses the period from around 1870 to 1920, during which a further level of technical achievement was reached. The industrial usage of electrical power on a larger scale, giving rise to sectors like electrical engineering that would go on to become extremely significant, was characteristic for the technical change during this period. Furthermore, the very first assembly lines (»Fordism«) and with them mass production based on the division of labour are seen as defining elements of the second industrial revolution. In Germany in particular, moreover, a growing connection between scientific research and industry was an additional distinguishing aspect of this period, being associated with the emergence at that time of the chemicals, optical and vehicle industries.

The ***third industrial revolution*** is also known as the electronic or digital revolution. Subsumed under this stage of industrial development are innovations starting in the 1970s

Box 1

that are associated with the advancing automation of industrial production (robots) and the mass use of computers. This notably includes the broad deployment of industrial robots, the programmable control of manufacturing systems by means of electronics and the rapid advance of the information technology industry at the end of the 20th century. Put simply, this period of upheaval is often described as the transition from the analogue world to the »digital age«.

The term »Industry 4.0« has been coined for the predicted, network-driven ***fourth industrial revolution*** starting in the present. At first, the catchphrase »Industry 4.0« was a marketing term employed by the German government for one of the future-looking projects under its high-tech strategy. Taking its cue from the usual denotation for new versions or updates (Web 2.0, iOS 7.1, etc.) employed in the digital jargon, the term suggests a new stage of industrial development. What started out as a buzzword in Germany has in the meantime become synonymous with the fourth industrial revolution. Neither term has become widespread (yet) in the English-speaking world, although this does not mean that the topic is not the subject of much debate in those lands.

A number of catchprases are associated with the expectation-arousing term »Industry 4.0«. What they all have in common is the intelligent connection together with the vertical and horizontal integration and communication of manufacturing processes in what are known as cyber-physical systems (CPS); systems that connect physical components (such as machines) with the digital realm and allow them to interact autonomously. This last point is the crucial difference in this regard: although computer-controlled automation is already the state-of-the-art following the entry of electronics, current software-controlled production is a purely static, reactive coupling between the »control device« (computer) and the »executing device« (machine).

In terms of the control technology, there is no (intelligent) feedback between sensors and actuators. It is at precisely this point that Industry 4.0 is expected to give machines the ability for interaction, self-analysis, self-configuration and hence self-optimisation across the entire value chain by integrating information and communications technologies (known as embedded systems). Thus, Industry 4.0 has become an umbrella term for many ideas, concepts and applications that are associated with these developments. Among other things, these include: big data, internet of things, machine-to-machine communication, smart factory, smart grids,[22] and smart products and services.[23]

Box 1

22 Smart grids: intelligent (electricity) networks making the adaptation mechanisms between supply and demand more efficient with the aid of information and communications technologies.

23 Smart products: intelligent feedback between products and users/producers.

All this together means that industry is facing major changes. Networking and digitisation are forcing their way into ever more sectors and will not stop before reaching manufacturing industry. But is this imminent upheaval in production more a revolution or an evolution? It is impossible to give a definitive answer to this question a priori. First of all, a revolution is a fundamental and sustained structural change of a system in a relatively short space of time, whereas in this regard evolution describes gradual, creeping change. It will only be possible to say for certain whether Industry 4.0 had more revolutionary or evolutionary qualities with hindsight. A look at the course of the previous industrial revolutions does, however, provide starting points for an appraisal. Unlike political revolutions, none of the earlier industrial revolutions happened suddenly, instead requiring a certain amount of time until they had completely penetrated the market. The first industrial revolution lasted around 70 years; nonetheless, this time was relatively short compared with the preceding era. Furthermore, the innovations were so evident that this phase is considered revolutionary. The same holds true for the second industrial revolution, which by contrast took »only« 50 years, because knowledge transfer became simplified during the course of advancing globalisation, which served to shorten the transition phases. Accordingly, the third industrial revolution occurred within somewhere around just 30 years. This implies that coming upheavals could take place in even shorter cycles. A further characteristic of past industrial revolutions is that they were not identified as such in their time and their extent was only recognised in hindsight.

This is the point at which Industry 4.0 is currently being identified as a potential fourth industrial revolution. Caution should be exercised when evaluating a possibly approaching paradigm shift only from the perspective of the prevailing opinion; only viewing the new through the eyes of the old. Indeed, alongside anecdotal bloopers (*»The internet is just a passing fad«*[24] or *»But what is it good for?«*[25]), underestimating an imminent upheaval can have serious consequences for market-leading companies (such as Kodak or Nokia) or whole industries (the record industry). At the same time, opportunities can also arise for new global players (like Google) and previously unknown markets appear.

A major systemic and technological change is taking place. What power to revolutionise it will have, and over what period of time it happens, will be a key issue for the German economy over the coming years.

Box 1

24 Bill Gates, 1995
25 An engineer in IBM's Advanced Computing Systems Division is quoted as saying in 1968.

3 The German business model

3.1 From »sick man of Europe« to globalisation winner

How times change. Less than 15 years ago, Germany was considered the »sick man of Europe«. Excessive labour and welfare costs, huge thickets of red tape and all-pervading regulation, coupled with burgeoning government debt and social and political gridlock, had severely weakened the country's competitiveness and flexibility. With almost five million people unemployed and anaemic economic growth, Europe's biggest economy hung like a millstone around the neck of economic development in the European economic area.

But instead of wallowing in self-pity and sinking into an apparently inevitable economic collapse, the ailing German economy picked itself up off the floor. The Agenda 2010 programme and other accompanying reforms initiated what by German standards was a radical change of direction in economic policy. The German labour market that had become badly glued up was made far more flexible; the social welfare system that was struggling with exploding costs together with systematic misincentives was modernised at key points. This programme of political reforms was reinforced by a new quality in the social partnership between trade unions and employers that led to not only moderate pay settlements related to productivity advances but also to more flexible labour relations at company level. As a result of these changes in the political and social environment, radical changes also swept through the corporate world. Germany AG was re-evaluated in light of the corporate strategies and companies returned to its old strengths.

Germany experienced a new economic spring arising from this combination of economic structural reforms, growth- and employment-friendly pay settlements and modified corporate strategies. Prior to the recent financial and economic crisis, the German economy was already recording what by its standards was a remarkable performance. At an annual average of 2.7 percent in the three pre-crisis years from 2006 to 2008, GDP growth was well above the potential growth rate, which was put at around 1.3 percent. Although German economic output then suffered a collapse of historic dimensions during the crisis in 2009, with GDP declining by 5.1 percent, the slump had been made good again within just two years. And following on from this, the German economy has continued to perform well overall in an ever more difficult international environment.

Germany's economic revival coincided with a period of accelerated global structural change. This acceleration can be explained by the interaction of a whole host of megatrends, including the increasing integration of the global economy, the growing industrialisation of emerging markets, rapid growth in the world population, ongoing urbanisation and rising shortages in terms of the environment and resources, to name but the most important of these trends. The German economy has benefited from this accelerated global structural change with its pattern of specialisation in the international division of labour. Germany became the big winner from globalisation.

From its former position as the sick man of Europe, Germany had turned into the locomotive of European growth in just a few years. The question of how Germany had generated this »second economic miracle«, and what business model underpinned the positive growth and employment figures, was debated at length. Germany's industry-based export success suddenly became the international model that everyone raced to reproduce. The UK strove for »new industry, new jobs«; France discovered a sudden enthusiasm for the German export miracle; and even the United States devised an economic strategy aimed at expanding the industrial base of the economy. Some people have, however, also come to consider Germany's economic successes sinister over the course of time, as manifested in the ongoing criticism of the German balance of trade surpluses.

3.2 Core elements of the German business model

The debate surrounding Germany's economic strength turns on what has been dubbed the German business model. Although it cannot be assumed that an economy as a whole with its numerous independent actors follows a certain business model in a similar way to a company, such a term might well prove helpful when trying to identify the essential structural elements.

So what are the key success factors of the German business model in this context? The cornerstone of the German business model is the strong industrial base. Industry accounts for a good 22 percent of value creation, placing Germany well ahead of the equivalent figures for comparable industrialised nations. Added to this is that industry's share of economic performance in Germany has essentially remained constant over the last two decades, whereas deindustrialisation has continued apace in other industrialised nations. Many highly developed industrialised nations have evolved into service economies, while Germany has essentially remained an industrial country.

The still closed and deeply entrenched value chains that characterise the industrial production process are a matter of fact directly linked with industry's strong showing. The German economy has not specialised in a few elements of the value chain; instead, it contains firms from just about every segment that are closely connected with each other through supply and demand relationships. This network of companies encompassing the entire value chain is a further key success factor in the German business model. Added to this is the fact that this network of companies is not shaped solely by major corporations, drawing its strength instead from the close interaction of efficient small, medium-sized and large enterprises. What are known as hidden champions – frequently family-run firms that are world market leaders in specific niche markets – play a special role in this regard. In its hidden champions, the German economy possesses a unique selling point in that almost one in every two of these enterprises has its head office in Germany.

Another success factor for the German economy on the global marketplace is its ability to combine industrial hardware with complementary services to form complete system solutions. Firms that apply such »hybrid« business models have the whole lifecycle of an industrial product in their sights. Where the global demand has concentrated on system solutions, German firms have developed successful offerings accordingly.

Even if the whole range of sectors across the value chain is represented in the German economy, there is a clear pattern of specialisation in German industry – consisting of efficient capital goods and highly productive semi-finished products. With this pattern of specialisation, German industry pretty accurately met the global demand profile as it developed during the course of the worldwide structural change, driven by the megatrends mentioned above, allowing it to gain the reputation as the supplier to the world.

Indeed, German industrial enterprises more than in just about any other economy have geared themselves consistently to the market opportunities arising from globalisation. The integration of German companies in the international division of labour, and hence their taste for globalisation, is very highly marked. All the relevant markets are targeted in this process, be it through export strategies or local production and cooperation arrangements – including in research and development.

Just as dynamic as the taste of German firms for globalisation is their focus on innovation. The companies know very well that they can only ensure their success on the global marketplace by carrying out intensive research and development (R&D) and turning the results gained into marketable innovations. German firms are subject in some ways to an innovation imperative, and they take a proactive approach to this imperative.

Customer proximity is another of the success factors in the German business model, with German industry developing specific strengths in its contact with the corporate world. This factor is closely linked with the pattern of specialisation in German industry on capital and semi-finished goods. Many companies form regular networks with their business customers, in which cooperation extends into the R&D function.

Enterprises have developed a further strength from the specific conditions in Germany AG. Germany is a high-cost location, and this is forcing companies to be extremely efficient in their production processes. Raw materials are in short supply in Germany, and both energy and skilled human capital are becoming increasingly expensive. Given such production conditions, Germany can only maintain its leading industrial position with high resource productivity.

Last but not least, it is important to consider the significance of the factor 'labour' for the success of the German business model. Product reliability and safety, together with the high innovation content of industrial products from German production and the high quality of the goods marketed in general, can only be ensured with highly trained workforces. The mix of skills from academic disciplines and skillsets acquired in the dual-track system of vocational training play a special role in this context.

The ten success factors of the German business model mentioned are not intended to represent a complete list, and they are also not of equal weight in terms of their significance. But taken together, and in the way they complement and reinforce each other, these factors do to a large extent explain the success of the German economy in the face of global structural change.

3.3 Impact of digitisation on the German business model

With its specialisation profile geared to industry and innovation, Germany has successfully adjusted itself to global structural change, benefiting from this in the form of growth and employment gains. Advancing digitisation is set to give new impetus to global structural change (see also Box 1, p. 20). It is a genuinely structure-shaping basic innovation, characterised by consistent refinements of existing technologies rather than being driven by a completely new technology. It is only the intelligent combination of these various technology lines that gives rise to its profound effectiveness covering all areas of life. The processing of large volumes of data (big data), cloud computing, the interconnection of value chains to form cyber-physical systems and new man-machine architectures based on quantum leaps in the development of artificial intelligence are playing a key role in this.

There follows a discussion of how digitisation could impact on the individual factors making up the German business model. Viewed sector by sector, the German business model focuses on industry. Although digitisation is set to reach all sectors of the economy, industry will in all probability be swept faster and more fully by digital structural changes. The term »Industry 4.0« puts this in a nutshell. All the elements and steps in the industrial production process will be connected to form a smart factory controlled in real time. But it is not just the industrial production processes but also the products of industry and their markets that will feel the full impact of digitisation – the term »internet of things« expresses this succinctly. Consequently, digitisation opens up a twin-track portfolio of opportunities for German industry. For one, enormous potential for rationalisation is appearing for more efficient, more cost-effective, faster and more flexible production; at the same time, completely new markets are opening up for industry-based products and solution packages.

The closed value chains that are today still a key success factor in the German business model will come under massive pressure to adapt in this process. Supply and demand relationships across the value chain will experience fundamental change. Major shifts are set to take place in not just sectoral but also regional terms as a result of the expanded connectivity potential and the completely new ways of structuring production processes. The time factor will also have a role to play. Up until now, value chains have tended to be refined successively, while digitisation entails massively disruptive elements. Production structures that have evolved over decades may be challenged overnight during the course of digitisation. The ability to adapt quickly is set to become the key to mastering the future in the digital age.

All companies are having to face up to this temporal challenge, be they large or small, publicly listed or family-run. Today, the deeply integrated and closely linked network of globally oriented corporations and numerous, efficient SMEs forms the entrepreneurial backbone of the German business model. It will be necessary to reconnect this network of companies as digitisation progresses. Not all – today still efficient – elements of this network will cope with the challenges of digital structural change; not all of the companies concerned will be able to develop the necessary »digital maturity«. Added to this is that completely new players from completely different economic segments will change – and even fracture – the industrial value chains. That internet firms like Google would attempt to enter car-making, for instance, would at best have raised a few eyebrows just a few years ago, while now it is a foreseeable reality.

The ability to combine industrial hardware with intelligent services software to form efficient system solutions that is entrenched in the German business model could prove to be a valuable asset in the digital age. Advancing digitisation should expedite the dematerialisation of production. The share of software in servo-industrial value-creation processes is likely to increase against the share of hardware. Hybrid business models that take account of this change in the composition of value creation seem certain to become more important. The contradiction between industry and services is set to diminish further as digitisation progresses. Today, industry-related services still play a role accompanying or complementing industrial production. In future, these service components in some value-creation processes could even assume the dominant role, in things like autonomous vehicles for instance, that are possibly determined more by the control software than the material components of a car.

The pattern of specialisation on innovative capital and efficient semi-finished goods in German industry, and the associated focus on business with companies, is coming under strong pressure to change from the technology advances subsumed under Industry 4.0. There are practically no capital goods, nor machines or systems, that will not be affected by digitisation. There is much to suggest that the level of digitisation in these goods – meaning their ability to communicate and interact with each other autonomously – will become the key parameter on the marketplace going forward. The greatest opportunities in the rapidly changing markets will be enjoyed by those firms that not only know how to exploit the advantages of digitisation and connectivity in their own production processes but also rely fully on digitisation in their product offers and their business models, enabling their customers to benefit from the advantages of digital change. This process will cause relations between manufacturers and customers to become ever closer, particularly because the internet also facilitates completely new connections between producers and consumers as a distribution channel. The lot size of one, being the cost-effective production of customised products and solutions, is becoming a tangible reality. In this digitisation of the customer interface, currently hardware-oriented German firms will be exposed to stiff competition from the cyberworld. Companies like Google, Apple and Amazon that previously had practically no role to play in the industrial value chain will occupy parts of the value chain for themselves with business models that are in places completely new.

Digitisation will help the world grow even closer together. Information in real time will be globally available, with people, machines and products connected across the internet of things encompassing the whole world. The value-creation networks will be restructured during the course of globalisation accordingly. This process will entail more than just extrapolating existing globalisation trends, as digital change will give rise to completely new perspectives in some areas. Major changes could arise for global trade, for instance. New technologies like 3D printing (see section 4) are facilitating a re-intensification of local production, with the need to export and transport material goods declining as a result. And the enormous productivity potential that accompanies the digitisation of production is likely to massively alter the global structure of value-creation networks. Production that was not previously viable at a high-cost location for cost reasons could now be raised above the profitability threshold again.

Top efficiency in the production processes, with products that make sparing use of the resources energy, environment and raw materials, is one of the criteria behind the success of the German business model. Digitisation is opening up completely new opportunities in this context. However, exploiting these possibilities requires enormous efforts to be made in the fields of research, development and innovation. With spending on R&D accounting for nearly 3 percent of GDP, Germany is among the leading locations for research in the world today. In order for the German economy to maintain its position in the global innovation marketplace, research and development needs to be geared more heavily towards digitisation. Today, German industrial research is still very hardware-oriented; material innovations on the software side come mainly from other countries. In this context, Industry 4.0 provides the opportunity, as well as the necessity, to maintain leading industrial positions into the digital age.

Digitisation will not cease to progress when it reaches the world of work either. On the contrary, the world of work is probably one of the areas of life that will be affected the most by digital structural change. At the same time, the imminent changes also spark the greatest social concerns and fears. The changes will be great – all the greater will be the uncertainty regarding the nature of those changes and how workers will be affected as a result. This uncertainty also expressed in the existing studies on the impact of digitisation on the labour market, which range from fearful horror scenarios involving the loss of millions of jobs through to rose-tinted spectacle views of a brave new world of digital work. It is impossible to track all of these arguments here, although it is possible to keep one thing in mind: the end of work as we have known it has often been proclaimed during the course of structural change in the past – this has not yet occurred. The German experience of the last 15 years demonstrates how an economy can be a winner on the labour market by consistently adapting to global change. And this should be the case with digitisation as well. Without doubt the rationalisation and hence redundancy potential with digital change is enormous. But just as enormous are the employment opportunities from new products, markets and business models. As is always the case with structural change, it will only become a problem if what is disappearing is not replaced by something new (see also section 7).

3.4 Is Germany ready for digitisation?

The further success of the German business model in the digital age will depend critically on the extent to which the German economy succeeds in not only adapting to this new facet of global structural change but also helping shape it. Digitisation will be the decisive factor in the long-run sustainability of the German business model. Digitisation will not leave any analogue niches; everything that can be digitised will be digitised at some point in time. Like every innovation, digitisation provides both opportunities and risks. If it succeeds in fully adapting to digitisation, the German business model has the ideal fundamentals in place to exploit the range of digital opportunities to the full. If, on the other hand, the German economy falls behind in the digitisation race, the potential for the German economy to suffer and decline must be considered particularly high.

The German business model that has evolved over the last 15 years – with its key success criteria of a strong industrial base, the closed value chain, efficient network of companies and consistent orientation towards globalisation and innovation, to name just the most important – has demonstrated that it can not only cope with rapid, even accelerated structural change but also benefit from it. There is no logical reason why this should not continue in the era of digital change. The internet economy, and hence the economies that take up leading positions in it, will certainly play a greater role in the digital age. Nonetheless, to be able to offer market-compliant products and solutions for customers in rapidly changing markets will also require efficient industrial enterprises boasting the right manufacturing skills in the digital world. In this context, Germany has every opportunity to evolve into the first-choice cooperation partner, thus defending its leading role as supplier to the world.

This conceivable development does, however, represent a possible scenario and not an automatic development. Economic success in the digital age will not fall into the lap of the German economy; as before, it will have to be earned. The main task in this respect will be to systematically build on the strengths of the German business model with regard to digitisation at the same time as eliminating identifiable weaknesses just as systematically. Without making any claim to completeness, six such potential weaknesses are discussed below that simultaneously imply a need for business leaders and politicians to act.

The hardware orientation of German industry, and hence of the German business model, used to be a guarantee of success, because global markets demanded precisely the kind of hardware that German industry produced. During the course of digitisation, software is likely to play an ever greater role in the newly forming value-creation networks in the form of intelligence manifested in hardware. German industry needs to develop more software skills in order to establish control over the entire value-creation process and not be downgraded to purely a hardware supplier. This is the only way of meeting the US-based software giants at anything like eye level in the cooperation arrangements that are forming. More German software competence primarily implies setting new priorities in research and development, not only in the companies involved but also in the public research landscape.

The internet of things – the real-time connection of products, devices, machines, systems and processes – encompasses both corporate and consumer markets. With the possible exception of the automotive industry, the success to date of the German business model was built for the most part on a good positioning in corporate markets. In the business-to-business segment, the strength of German industrial enterprises rests in global markets. This focus on corporate customers could be a disadvantage in the digital age. While it is true that digitisation will give rise to major changes, and hence also opportunities, on the business markets, only targeting these opportunities would, however, mean foregoing large parts of the chances arising from digitisation. German companies need to pay closer attention to end users again, without neglecting corporate customers in the process. This would also be important for the social acceptance of industry and technical progress, as this is determined less by the efficiency of industrial production processes and more by concrete products and solutions that offer consumers direct benefits.

The clock rate in the digital world will be much faster than that known in the analogue world. Adaptation speed and flexibility are becoming the keys to economic success. Up until now, German firms have been renowned primarily for the successive refinement of existing products and processes through to perfection. The ability to quickly take up and implement new ideas and concepts is not, however, to be found across the board in the German economy. There is a long list of significant innovations with scientific-technical foundations in Germany, but whose roll-out on the market took place from other countries. A major rethink is required in this regard. Industrial production needs to adapt to the pace of change in the internet economy, at least in broad terms. Only those industrial enterprises that speak the same language in terms of speed will be able to establish themselves as cooperation partners on an equal footing with the leading internet firms.

As well as German companies have mastered global structural change to date, it is all the more important to ask how well prepared companies are for the digital challenges. Current surveys and studies demonstrated clear shortcomings in this regard.[26] Although almost all companies are looking into digitisation, only 70 percent of them consider it a major challenge. Whereas three quarters of companies have a positive attitude towards digitisation, 20 percent of small and mid-sized enterprises reject digitisation. A good one German company in three still has no digital strategy. While most companies see opportunities for their own firm primarily in possible efficiency gains in production, fewer of them spy chances in new products, markets and business models. These only highly fragmented findings provide indications for a gap in the »digital maturity« of German firms that cannot be readily dismissed. Both the opportunities and risks of digitisation are underestimated by not a few companies (Figure 5).

26 Roland Berger (2015).

Digitisation is changing business models

Which statements relating to digitisation are true for your company?

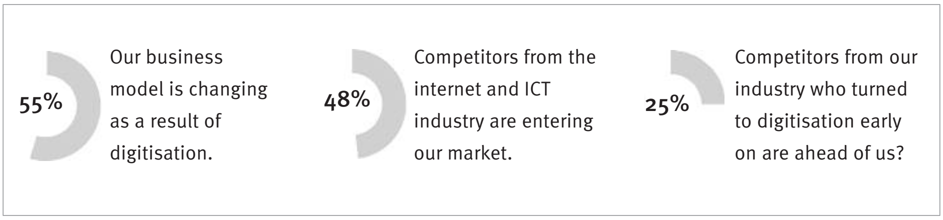

Fig. 5 Source: Bitkom Research.

The internet economy, and hence the digital economy, is being shaped by young firms and start-ups more than practically any other sector of the economy. All the major internet firms, be it Google, Amazon or Facebook, are relative newcomers in the global corporate landscape. In terms of successful start-ups, the German corporate landscape is relatively barren, with far fewer firms being set up in Germany than is the international norm. Start-ups from the technology segment in particular find it hard to obtain the necessary financing. The same holds true especially for the early stages of company development during which economic success is still uncertain and the technical risks are still high. Basically, it is not possible to speak about a genuine venture-capital market in Germany to roughly correspond with that in the United States. This has less to do with underlying tax and legal conditions and more to do with the marked aversion to risk shown by domestic investors (Figure 6). It is absolutely essential for this mental brake on innovation in Germany AG to be overcome, otherwise good technical ideas from Germany will seek their financing and hence their location somewhere else.

Worldwide comparison of venture capital

$ billion

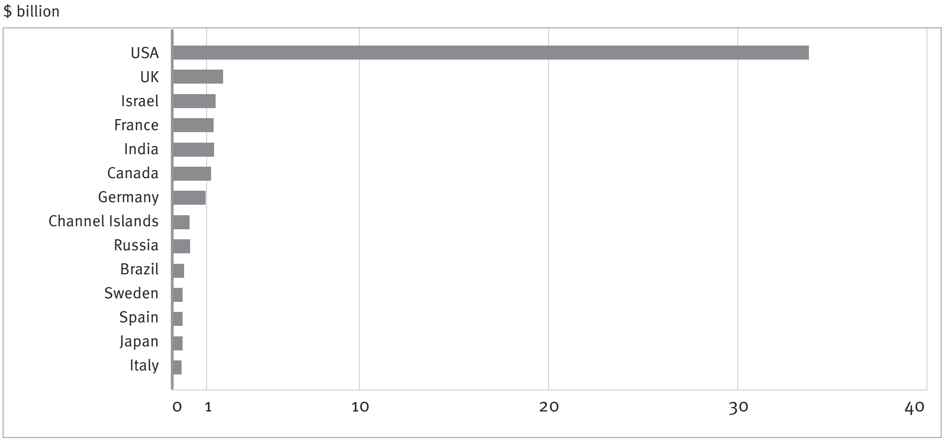

Fig. 6 Source: McKinsey, Capital IQ.

Average broadband speed

Mbit/s

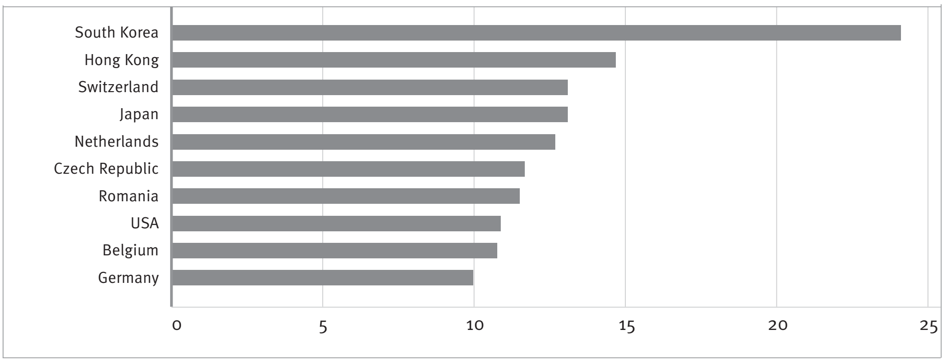

Fig. 7

Source: AKAMAI, quote from BDI.

It will not be possible to unlock the full potential of digitisation unless the technical network infrastructure is kept constantly state-of-the-art. This applies to both technical performance and the requisite security of use. Data security is a particularly sensitive issue in Germany, for both citizens and companies. Politicians and business leaders would be well advised to take this into account in their digitisation strategies, not least because security solutions also define markets. Germany lags behind in terms of the technical infrastructure for the digital age. Fast and reliable broadband networks – be they fixed-line or mobile – are the arteries of the modern digital economy. Their expansion must be progressed vigorously (Figure 7). There is plenty of placeable investment capital available in Germany – it just needs to be mobilised.

4 3D printing: economic disruption potential?

Today, there are already hundreds of studies dealing with one of the best known new technologies: 3D printing. But few people have looked into the macro-economic potential of this technology to date – economic forecasts that calculate the impact on growth or productivity to the second decimal place are too difficult. Yet additive manufacturing – as 3D printing is also known – is of great interest and relevance in macro-economic terms: the technology is a prime example of the digitisation of our economy, on the basis of which we can describe the macro-economic disruption potential of new technologies for both the German economy and its global counterpart. This is precisely what we do below. In this context, we do not claim to predict the future with any great certainty; we will merely sketch the outline of a future domestic and global economy permeated by 3D printing on the basis of a few assumptions.

4.1 3D printing – What exactly is it?

3D printing has not yet become very widespread generally. But its use is already standard in some areas of industry. In the aviation industry, for instance, this method is employed to print fuel injectors for engines. Siemens employs additive manufacturing to produce parts for gas turbines. To date, consumers have mainly come across 3D printing in things of lesser importance: 3D-printed figures and mobile phone cases, or the 3D-printed – functioning! – gun that was made famous by a YouTube video. Chinese building contractors use 3D printing to print complete parts of prefabricated homes. And additive manufacturing has already been used by the food industry, in the production of chocolate, pizza dough or even burger meat, for instance. The current situation is that 3D printing is used primarily for single-item runs or low volumes of complex goods. Surveys do, however, suggest potential for serious changes in our everyday lives: A study by TNS Emnid commissioned by Reichelt Elektronik determined that 69 percent of Germans could imagine buying a 3D printer, with 10 percent determined to buy a 3D printer whatever. Almost one in four 16 to 24-year olds (24 percent) and 25 to 34-year olds (23 percent) would be willing to use a 3D printer to prepare a meal.[27] Many experts doubt that 3D printing will ever be suitable for series production or the rapid manufacture of individual products as it is very slow at present. But this will not prevent us from working through in our anecdotal forecast what might happen if 3D printing technology did become established on a large scale.

The underlying assumption for our scenario is that the ongoing development will make 3D printing ever more attractive for mass and series production and ever cheaper generally, in terms of both input materials and printer costs. In addition, we believe – admittedly somewhat speculatively – that print speeds will also increase significantly.[28] Our assumption is based on the view that it was almost always the case over history that technological progress has led to manufacturing processes becoming more accessible, more reliable, faster and above all cheaper over time: the letterpress, the steam engine, the assembly line and so on (see also the box about industrial revolutions

27 Cf. Presseportal (2015).
28 Being economists, we do not feel called to forecast technological developments, our goal is only to derive the possible economic implications.

in section 2). And that a machine that manufactures complex products can also produce simpler products is a conclusion that practically draws itself. Added to this, as already implied above, is that 3D printing has already been successfully employed in a wide range of sectors, from clothing and medical and dental engineering through to the food industry (see below for more about the impact on different sectors).

A 3D printer is a machine that builds three-dimensional components layer by layer. The process is computer-controlled using one or more liquid or solid components following a set of digital instructions. The process of building the product is based primarily on physical or chemical hardening, compression or fusion processes. Typical materials used as inputs for 3D printing include plastics, synthetic resins, ceramics and metals. This contrasts with the traditional production of physical goods. Normally, a piece of metal, wood or other raw material is worked and »reduced« to the correct shape – meaning smoothed, planed, fused – in order to obtain a completed object at the end. But these objects are by no means finished goods. A screw, for instance, is milled from a mould-cast metal block in order to later join together two further objects in a larger product. In additive manufacturing, on the other hand, the object is built up layer by layer.

4.2 Macro-economic implications

This simple difference in production implies that production flow is also different in nature. By the nature of reducing production, more input is generally needed than output; in additive manufacturing, this is much more rarely the case. The first macro-economic consequence of this is that, by producing less waste, the technology contains potential for more efficient use of resources. Added to this is that, in conventional production, various semi-finished products often come from a wide range of production facilities, meaning that both transport costs and the coordination of a production chain become relevant issues. It is true to say that the more elaborate the product, the more complicated the conventional production chain. The manufacturing steps upstream of 3D printing are quite different: the focus shifts away from the assembly of various semi-finished products and towards the sourcing and provision of a wide range of raw materials in the form of granulates.

This gives rise to further macro-economic potential, with what can be described as genuine disruption potential. The structure of world trade could fundamentally alter, depending on the spread of 3D printing. Other things being equal, more and more raw materials, and fewer and fewer semi-finished products, would be traded. No matter whether it sits in Silicon Valley or central Africa, a 3D printer only needs electricity, correct operation and of course the granular raw materials. The consequence is that more finished products would be manufactured locally, and mainly raw materials would be required rather than semi-finished products.

This would go hand in hand with a reorganisation of multinational companies. The cross-border value chains of multinational firms would be deconstructed again. In the case of car, for instance, the seats might be made in Hungary, the tyres in the Czech Republic, the engine in Spain, and the whole thing finally assembled in Germany. The more semi-finished products can be manufactured locally, the less it is worthwhile for companies to split up their production geographically. The classic comparative advantages would become less significant for the structure of world trade. Differences in the factor endowment of an economy (human capital, natural resources and capital) or labour productivity between countries would be less important.

The spread of local production as a result of 3D printing would also reduce the need to coordinate long, complex value chains. Logistics, an essential part of industrial production, would change accordingly. There would be far less of a need to transport products and semi-finished goods across international borders than is the case today. Transport would concentrate on the goods that cannot be 3D-printed, meaning both more valuable goods, mainly capital and investment goods, on the one hand, and of course raw materials on the other. Trade in simple consumer goods and less complex everyday, capital and consumer goods would probably decline rapidly, if the only things that need to be transported from A to B are the 3D printer and the inputs for printing. The re-regionalisation of production would therefore be one consequence of the spread of 3D printing.

In parallel with this re-regionalisation, the role of transport technology and transport costs for the global economy would also change. As discussed above, it would simply no longer be necessary to transport many goods. This would also lower fuel needs. In economic terms, this means that the global economy would be less heavily affected by fluctuations in the oil price. Similarly, infrastructure programmes would presumably be less effective in generating economic growth. The lower transport volume simply does not call for such any more. By contrast, warehousing of input materials would rise. The expansion of just-in-time delivery of particular inputs for the 3D printing of food, for instance, would be just as likely. Additive manufacturing would probably, on aggregate, have primarily import-substituting effects for the domestic industry in every country. Much more would be produced at home again. The consequence for the global economy could be that fewer industrial goods are traded. It seems likely that a whole new industry providing professional services for 3D printing will evolve. This would involve not only maintenance and input sourcing but also the »printing instructions«. All of this does of course represent another major challenge for the protection of intellectual property. For one thing, trade in free printing plans is likely to flourish. At the same time, a completely new, global market might emerge under the right conditions, such as making printing instructions available for temporary or one-time use. Added to this would be the regulatory framework – it should presumably not be possible for someone to be able to »print« a gun just like that. To achieve this, a new regulatory culture capable of responding quickly to new developments would need to evolve.

Trading in a wide range of raw materials required for 3D printing would increase. As already mentioned above, this relates first of all to plastics based on polymers, which in turn are produced from crude oil. Synthetic resins are also included. These are produced synthetically by means of polymerisation, polyaddition or polycondensation reactions; these are based on synthetically produced phenols that can also be extracted from tar in anthracite and lignite. Things like cellulose, ceramics, various metals or even sugar or meat granulate are other inputs. This means that the chemicals industry would profit from the spread of 3D printing. Trading in precisely these inputs would presumably increase dramatically. In the case of Germany, this would primarily mean that the plastics produced from crude oil would continue to entail a high dependence on imports. Countries with a less well developed chemicals industry would, moreover, need to import more of the inputs listed above.

The expansion of 3D printing would represent a great opportunity for the German economy. Together with companies and research institutes from the United States and China, the domestic industry is a global leader in the production and development of 3D printers. Yet the American and Asian competition is not sleeping, which makes it difficult to provide concrete forecasts. Consolidation is not even on the horizon. And yet, according to a study commissioned by the German Federal Ministry for Economic Affairs and Energy, 92 percent of German 3D print companies are SMEs.[29] Furthermore, we estimate that 3D printing could potentially be used by at least 60 percent of the German export industry. This would mean 3D printing having an impact on the structure of the economy across the board. The consequence would be less disruption potential and more expansion potential for the German balance of trade: while even more high-tech 3D printers would be exported around the globe, fewer semi-finished products would be imported, set against more raw materials, which in turn would be of less value on average.

The mass spread of 3D printing would of course also have an impact on the structure of employment. Here, too, we expect to see a polarisation. For one thing, the demand for well-educated engineers who build and develop the printers is likely to rise. Furthermore, the demand would rise for design engineers who can draw up the print instructions mentioned above. At the same time, conventional industrial jobs would in all probability disappear. The maintenance and service sector relating to 3D printing would, in turn, expand. The skills required for such services would, however, probably be much lower than the average skillset of a skilled German worker. In this respect, 3D printing contains further potential to disrupt, as it will advance what is known as »skill-biased technological change«, being technological progress from which mainly people with a good, academic education would benefit (see also section 2). People with a primarily practical education could, by contrast, tend to lose touch – at least in the short run. It is, however, not necessarily essential to make a negative assessment of this phenomenon. The ongoing development of human capital and a balanced combination of education and training, above all in technology-related fields, could not only cushion the structure-changing effects of 3D printing but also help to ensure that every single person benefits from the advantages of the new technology. Furthermore, history teaches us that technological progress can only be delayed, not stopped altogether. We look forward with interest to the future.

29 Cf. Astor et al. (2013).

Consumer goods – traditional and »disrupted« delivery chains

Consumer goods – traditional supply chain
Raw materials → Processing → Distributor → Retailer → Consumer

Consumer goods – disrupted delivery chain
Raw materials ↘
Print instructions ↗ Home 3d printer → Consumer

Fig. 8 Source: Berenberg.

3D printing represents a further challenge for the protection of intellectual property. As a result of the fact that the print instructions mentioned above take centre stage of 3D production, the digitisation of the world is likely to trigger a massive change in how these instructions and plans are dealt with: companies would increasingly earn money by developing construction and printing instructions that customers then print out for themselves. The competition would move away from issues surrounding the rapid provision of products (and their delivery) and more towards customised and/or particularly innovative ideas and plans derived therefrom. A Wikipedia of construction plans could emerge, for instance, or companies could build half-lives into their construction plans, so that they can only be used for a set period of time (or by a set number of printers). At the same time, this also means that piracy could increase and that people could print »things« that it would probably be better if they did not have in their hands – the best example being the gun mentioned above. So lawmakers need to deal with the security-policy challenges that the new digital technology brings with it.

Finally, 3D printing could also revolutionise the way we consume and the way we live day to day. To make a prediction in this regard, we apply the assumption that a 3D printer will be available in just about every household in the future just like a telephone, fridge, television set or microwave is today. Local providers of printing services in places like DIY stores would evolve for larger objects. Today, raw materials are first treated until they are ready to be processed, then further processed and finally distributed by wholesalers and then retailers to the final customers. The history of consumption provides an interesting parallel here. In the 1950s, the car and fridge enabled people to do ever bigger shops (ultimately in ever larger shopping centres) at ever greater intervals – the traditional weekend shop. The spread of 3D printing is likely to produce the contrary: the wanted goods would in future simply be printed at home goods when the need arose. All it takes is to buy printing instructions online and then simply print out the desired product.

Against this backdrop, the disrupted supply chain for consumer goods (see Figure 8) holds enormous economic disruption potential: the supply chains from toys and furniture, paper clips, clothes or garden implements through to foodstuffs could change fundamentally: processing, distribution and also retailing would become superfluous – just like the weekly shop. At the same time, 3D printing of consumer goods used or required every day would be far more consumer-oriented than conventional »off the peg« products. Weekly shops would then serve mainly to buy in the raw materials required for printing at home.

Conclusion: 3D printing has enormous economic disruption potential. The more the technology gains production speed and printer prices fall, the greater the macro-economic consequences are likely to be. The structure of external trade and multinational production – or globalisation as we know it – could change fundamentally, as could the types of production in a wide range of industries. Not to mention the massive changes seen in everyday consumption.

5 Digitisation and the automotive industry

The automotive industry is facing major systemic and technological upheavals. New competitors and previously non-industry global players from the digital world are pushing into the mobility sector: Tesla is finally becoming established on the market and is reporting rapid rises in sales volumes together with record revenues, and Google has bought up automotive know-how throughout the world and spectacularly presented a self-driving (robot) car.[30] In addition, the rumours are increasing that Apple wants to enter the mobility market with an electric car.[31] A kaleidoscope of companies with differing backgrounds, self-images and corporate cultures is emerging that are doing battle for future shares of the multi-billion mobility market against the backdrop of advancing digital penetration of all areas of life. In this context, the enormous opportunities are set against tremendous risks, and the odd requiem for the established automotive industry can already be heard alongside the calls to create new, profitable business models and enter markets. And this – previously rather exclusive – group of car-makers is taking the threat seriously; no one wants to be the next steel industry or another Kodak or Nokia. Although the days when cars operated as purely mechanical objects are long gone, while digital elements have been industry standard for ages and cars are increasingly coming to resemble rolling computers, we are nonetheless just at the start of a digital sea change in the mobility market.

30 Cf. Reuters (2015); ZEIT ONLINE (2015b)
31 Cf. Spiegel Online (2015).

Robot density in the automotive industry and general industry, by selected countries worldwide, 2013

Number of robots per 10,000 employees

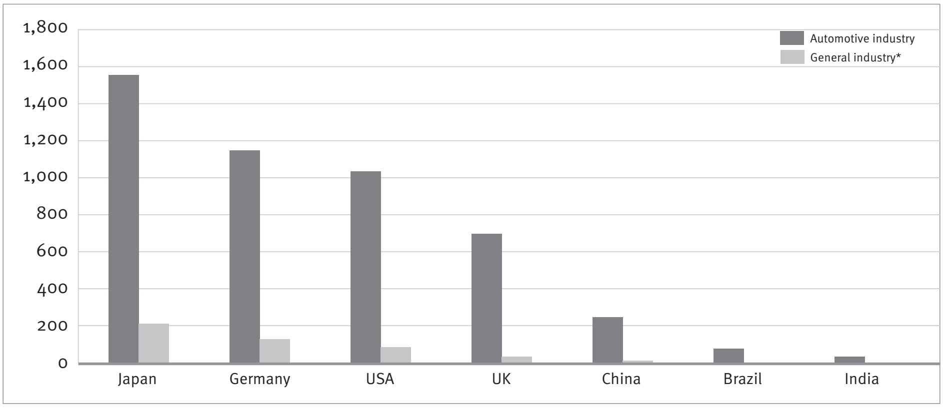

Fig. 9 * The source uses the term of »general industry« in this context. Sources: KUKA AG (2015); HWWI.

Against this backdrop, it is especially informative to take a look at the possible major trends. Digitisation will in probability fundamentally change the car, thus helping to shape the future of both mobility and the automotive industry. Germany in particular, which is associated with its automotive industry more than any other country, needs to keep a very close eye on imminent changes and possible trends in such a key industry as car-making.

Possible trends and conceivable perspectives in the mobility market are outlined and placed in the right context below, and the central challenges for the automotive sector are presented and discussed. The analysis deliberately does not focus on the influence of digitisation on production and manufacturing (as in smart factories, for instance). For one thing, this would enlarge the scope of this study too much, while the automotive industry is already relatively well advanced technologically in terms of its manufacturing and production processes (Figure 2). Commingling the various aspects of digital change would make it harder to identify different technological contributions.

5.1 Development trends

What does the future hold for the automotive industry in the context of digital change? Anyone wanting to answer this question and identify the trends arising from the ongoing digitisation could well find that a glance at the (well-guarded) development plans of the established automotive corporations proved inadequate for determining the significant long-term trends and future innovations. It is the digital world that is bringing a new dynamism into the car industry from outside. In this context, the impetus is not limited to the digital corporations like Apple or Google that are penetrating the mobility market, but also additional dynamics triggered by changing consumer preferences and buyers' digital habits. Digitisation – in all its variants and facets – is changing far more than just the technical possibilities; in places, digital development goes hand in hand with a change of mentality that challenges entrenched, habitual patterns of behaviour in mobility.

When considering the future of the automotive industry, therefore, it is impossible to avoid starting one level higher and asking about the future development of mobility itself. Numerous trends are shaping mobility: the digital penetration of almost all areas of life, a growing world population, advancing urban consolidation and increasing awareness of ecological and sustainability issues are just a few examples.[32] The analysis of these general trends and the conclusions drawn from them are critical for the future of motorised private transport and its providers. For the automotive industry, these developments almost certainly mean radical changes in business models over the coming decades.

The automotive industry is traditionally highly innovative. So great caution should be exercised when making predictions about trends. It is nonetheless possible to draw conclusions from history and the present and to describe, discuss and classify potential development paths.

5.2 Mobility

The mobility sector has experienced massive innovation over the last two centuries in particular and developed an incredible dynamism that has helped shape society, environmental issues and the economy. Mobility patterns have also changed constantly in the process, closely linked with social changes and technological developments. The transport industry started to change rapidly two hundred years ago with the first industrial revolution; the arrival of steam engines (railways, steamships) served to greatly increase physical performance, making transport independent of muscle power (horses) and weather conditions (wind, currents, seasons) for the first time.[33] At the same time, the innovations in the transport segment were not simply a result of the first industrial revolution but more its driving force at the same time thanks to more mobile technology transfer.

But the far-reaching and most dominant change in the transport industry to date started at the beginning of the 20th century. The invention of the internal combustion engine and the diesel engine, coupled with the onset of mass car production, ushered in an era of personal mobilisation.[34] To this very day, the ensuing patterns of behaviour, thought and values have shaped the concept of mobility: automobility. It was not until the advent of private motoring that the physical separation of living and working became possible, suburban settlement practicable and short to medium distances readily superable. Consumption and lifestyle adapted to this newly gained mobility to become deeply entrenched in all industrialised nations today. Mobility has become a modern matter of course.

But what is mobility and what needs does it meet? In short, it is basically a change of location occasioned by movement: transporting a person from A to B. Such transport serves to meet other

32 Cf. Oliver Wyman (2012).
33 Cf. Rammler (2014).
34 Cf. ebenda.

(primary) needs: travelling to the place of work, socialising, enjoying spare time, and much more besides. Furthermore, an intrinsic need for mobility can also arise: the pleasure of driving and also the upgraded status implied by the vehicle.[35]

The modern automobile has been able to meet these needs best to date and will presumably continue to do so in the immediate future. Nevertheless, this form of mobility is increasingly pushing up against its economic, infrastructure and ecological limits. As the world population expands, and with it the demand for transport and urbanisation,[36] the negative external effects of mobility are growing as well. These include emissions, smog, shortage of space, traffic jams, road traffic accidents and rising resource consumption. The question needs to be asked whether and how mobility can be facilitated and organised for a rapidly expanding population, given existing patterns of mobility.

New mobility concepts could start to compete with established vehicle-based personal mobility and provide answers to the problems of rising demand for mobility. But of course only they are at least just as effective, meaning they ensure reliable movement from A to B. Moreover, where new mobility solutions promise an additional benefit compared with existing concepts (such as lower costs, greater safety, greater comfort, greater sustainability, more time, a wider range of services, greater flexibility and so on), there exists the potential for pervasive change in the market.

5.3 Digital revolution

There are quite a few observers who see the potential in the digitisation of mobility for unprecedented change with an outlook for new mobility concepts having the ability to tangibly reduce the unwanted side-effects of mobility and the capacity to increase the benefits for the individual road user at the same time.[37] Some people go so far as to ascribe even greater revolutionary power to digital change with a »digital reinvention of mobility«.[38] Whether one agrees with the prophesied dimensions of the change or not, it is beyond dispute that the mobility market is becoming rapidly more digital and the established automotive industry is facing major systemic challenges. The most important digitisation trends are presented below together with the key considerations and consequences for the automotive industry.

5.3.1 Changed technical possibilities

Digital components in the car became a reality long ago. There are sat navs, distance sensors, stability programmes, lane assists, blind-spot detection systems, tiredness sensors and park assists, to name but a few. In the car of today, information and data from the surroundings are already recorded and digitised autonomously by an array of ambient sensors, linked together and integrated in the driving process. And the entertainment system in most cars is almost completely digital as well. Thus, the modern car is already a rolling computer today. How can and will far-reaching digitisation proceed?

35 Cf. Zängler (2000).
36 Cf. UN (2014).
37 Cf. Roland Berger (2013); Boston Consulting Group (2015).
38 Cf. Rammler (2014).

The next crucial step will come in the intelligent connection of the available traffic data, entailing constant, two-way communication between vehicles with each other and their surroundings. This will require the intelligent collation of on-board camera and sensor data (including position, direction, speed and destination data) and environmental data (such as the weather, the state of the road and traffic conditions) provided by the road user with that from other vehicles and the infrastructure. In this connection, the terms 'car-to-car' (C2C) and 'vehicle-to-vehicle' are employed for communication between cars, and 'car-to-X' (C2X) and 'car-to-roadside' for communication between car and infrastructure. For this to succeed demands an efficient network infrastructure that guarantees a permanent, completely reliable and above all fast connection between the vehicle and the data networks. It is not yet absolutely clear how the collation of the data will be implemented technically in the next step. Direct communication by radio or internet between the cars is just as conceivable as data transfer using mobile terminals belonging to the vehicle driver.

The goal is ongoing, real-time evaluation of this huge volume of data (big data) and the corresponding, intelligent redistribution of the relevant data to the vehicles. A wide range of functions and improvements could be realised with the aid of such an intelligent information exchange (smart data) in what could be a further step towards (fully) automated driving. Irrespective of the technical implementation, the function and the potential of such broad-based data collation are quickly identified. One example is road safety. In a network comprising smart traffic infrastructure, possible dangers such as accident sites, the sudden start of traffic queues and black ice are immediately notified to potentially affected road users so that they can react to the hindrance immediately by automatically driving around the danger point, for instance, or reducing speed autonomously. The possibilities for active intervention by forward-looking driver assistance systems will grow strongly in the connected mobility world. Possible critical situations are identified earlier and are easier to deal with. Despite still widespread reservations about these technologies, the increase in safety together with the associated savings in accident-related costs are likely to gradually boost acceptance of these developments.[39]

Moreover, an intelligently connected vehicle fleet provides opportunities for making road traffic more efficient. In a type of central planning approach, enormous efficiency potential can be unlocked by collating and analysing data from navigation and information systems. Better traffic management, optimal road usage, routing optimisation and active tailback avoidance are a few possible examples of digitised traffic infrastructure. The advantages of the digital optimisation of the traffic flow are self-evident: the road-user enjoys a smoother ride thanks to fewer traffic jams and lower journey times. In addition, shorter journey times help to save fuel and reduce the consumption of economic resources. More efficient use of roadspace and optimised traffic flows are set to become more important in light of urbanisation in particular, thus giving further impetus to the concepts of smart traffic.[40] As a result of the pressure to adapt in the megacities, the mobility of the future and the associated business models will tend to emerge in the major metropolises.

39 Cf. Deloitte (2014).
40 Roland Berger (2013) puts the annual cost of congestion in the 30 biggest megacities at $266 billion.

The fields of entertainment and infotainment, navigation and other onboard services will become increasingly relevant and gain further shares of value added in the digitised car of the future. The better integration of smartphones as currently being discussed will be just the start in this. In the medium to long term, the pressure is likely to increase to offer consumers similarly sophisticated interfaces and operation (with app control, for instance) as they are used to from regular interaction with their smartphones and tablets. This means that customers will in future probably be less willing to accept antiquated control elements in the vehicle console compared with the smartphone. The phenomenon is not unknown that the digital control unit is already obsolete when a new car is rolled out.[41] This effect may come about due to the different development cycles for the car and the control unit. Moreover, service offerings are set to gain greatly in importance alongside the digital hardware. In a similar way to the (mobile) phone, the car is likely to increasingly become a medium for content and services. These onboard services may consist of information offerings, entertainment and communication provision, augmented reality services, location-based services and numerous other conceivable offerings. It is in such content segments that buyers may well see additional product differentiators. The digital features will become more important selling points, thus changing the balance between vehicle engineering and features.

5.3.2 Changed consumer preferences

Alongside the purely technical possibilities thrown up by the digitisation of mobility and the car, a constant change in attitudes towards mobility can be observed. In cities in particular, more and more people are willing to forego owning a car. A life without their own car has become completely imaginable for many young city-dwellers, although one without internet and smartphone is not. All the same, a fall in demand for transport cannot be derived from the creeping rejection of car ownership. On the contrary, the degree of mobility is set to go on expanding. It is safe to assume that the demand for mobility will continue to rise going forward.[42] A change in values is taking place mainly among the urban, technophile »internet generation«, the generation of digital natives that will comprise the consuming classes of the future.[43] Digitisation has a crucial influence on how mobility is being perceived and consumed by this generation.

To a growing extent, ***using*** is being placed ahead of ***owning.*** Flexible usage models are becoming more important than ownership in some areas. This phenomenon is closely linked with digital change and the ensuing organisation possibilities. It has been particularly possible to observe this development in the digitisation of the music and film industry. Here, people pay for constant access to a consumer good (streaming services) in music or video portals rather than for their own physical copy of a medium (CD/record collection). The market has turned from a product market into a service market. A transformation in a similar direction could be experienced by parts of the mobility market of the future, with the ownership of a vehicle becoming dispensable in economic and emotional terms, while the demand for access to non-proprietary (multimodal) mobility

41 Cf. Spiegel Online (2013).
42 Cf. KPMG (2013).
43 Cf. Oliver Wyman (2012).

Number of registered car-sharing users in Germany, 2008–2015

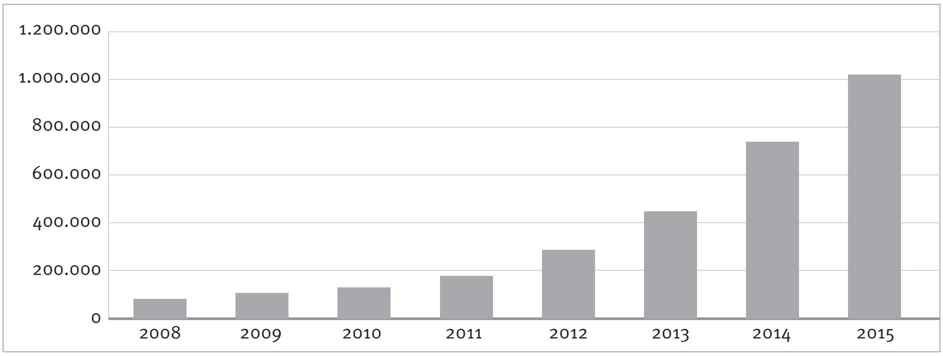

Fig.10

Sources: Horizont; Bundesverband CarSharing; Statista (2015); HWWI.

solutions rises. In this case, mobility will be organised across the entire mobility system instead of through a specific mode of transport, such as the car.[44] It is the information systems provided by digitisation that facilitate a seamless transition between various transport solutions.

The perception of values is also changing, with the car experiencing a slow loss of value as a status symbol and object of prestige. It is not without good reason that the share of bicycles on urban roads has risen over recent years and the proportion of people with driving licences has fallen in the major agglomerations and among the younger generations.[45] Added to this is the fact that it is constantly becoming easier to coordinate and implement demand-compliant mobility concepts thanks to connectivity (using devices like smartphones).

»Using instead of owning« is an article of faith in the sharing economy. In the mobility market, it primarily means car-sharing, bike-sharing, car-pooling, local public transport, and their intermodal combination. The idea of car-sharing is nothing new and has been around for decades, but digitisation has caused the user figures to explode. The number of registered car-sharing users in Germany increased by a factor of nine between 2008 and 2015 (see Figure 3). And bike-sharing schemes are also recording growing popularity in the modal split in the major European cities as are the ride-sharing offers.[46] Forecasts suggest that the number of users in Europe will rise by a factor of twenty from 0.7 million to 15 million in the period from 2011 to 2020.[47]

It is only digital change that has made these mobility solutions possible on a larger scale and with a new quality. The kind of convenient usage that people expect these days regarding transport has only been rendered feasible for the tasks of finding, organising, combining and selecting from among the many transport solutions by the provision of smartphone apps and internet-based platform services.

44 Cf. Roland Berger (2014a).
45 Cf. Henkel et al. (2015).
46 Cf. Schade et al. (2014).
47 Cf. Frost & Sullivan (2012).

5.3.3 Disruptive innovations: e-mobility and driverless cars

Two possible developments have the potential to massively accelerate the trends and upheavals described above: e-mobility and driverless cars. Whereas understandably the broad market penetration of electric cars primarily affects only vehicle engineering, self-driving cars would represent a turning point in the mobility market. Digitisation is component and driver as well as essential prerequisite for both game changers.

E-mobility: There are many hurdles that still need to be overcome before electric cars can seriously compete with models running with conventional engines: electric cars are relatively expensive and have a shorter range than conventional vehicles; there are few different models; and the recharging infrastructure and charging times are still inadequate. Even though the number of new registrations[48] of electric cars is still extremely low at present compared with vehicles with internal combustion engines for the reasons stated, much is happening on the market nonetheless. All the major car-makers are involved in research and development for electric cars and are pushing innovation. Large amounts of money are being invested in research into batteries and the use of lightweight construction materials.[49] There is probably still a long way to go before e-mobility becomes broadly established on the market, yet the consequences for the established automotive industry would be grave. Cars with an electrified power train do not have a conventional engine or transmission. Market penetration by electric cars would be tantamount to structural rupture with the potential to render whole sub-industries in the existing automotive sector superfluous. Large parts of the expertise gained over decades and the patents held by the conventional car-makers pertain to specifically those »engine-related« elements and stand to lose much of their value. Digitisation will play a key role in the success of e-mobility. Electric cars will not become practicable in everyday life until there is a connected infrastructure that helps people locate and reserve free recharging points or remotely monitor charging levels.

Autonomous driving: Completely driverless cars would completely change the situation on the mobility market and the perception of mobility.[50] Irrespective of prototypes like the Google car, the developments by the major car-makers are also moving from today's driver assist systems and semi-automatic driving in the future towards the vision of a driverless car. Autopilots in aircraft and ships are standard these days. Even though road traffic is considerably more complex, the vision of a completely autonomous vehicle that autonomously analyses the traffic and manoeuvres within it is not that far removed.

The biggest obstacles to driverless cars are currently more of a legal nature than technical. Questions of responsibility and liability in the event of road accidents through to ethically ambivalent decisions which would need to be programmed just in case have not been fully answered. Assuming that such conflicts are resolved, the driverless car would, however, render mobility concepts and possibilities together with business models conceivable that were previously not possible, with far-reaching implications for the automotive industry.

48 In Q1: 0.6 percent of new registrations (incl. plug-in hybrids) in Germany. IHS Automotive (2015).
49 Daimler, for instance, invested €100 million in its own battery systems at the beginning of 2015 (Daimler, 2014).
50 Cf. Roland Berger (2014b).

Without digitisation and strong connectivity between cars and traffic infrastructure, autonomous driving on a large scale is not practicable, however. To navigate securely, a computer-controlled vehicle requires the data from its surroundings and other road users. Thus, in the first stage it is reliant upon a digital environment. In the second stage, the driverless car would then in turn be a massive driver of further digital value creation in the automotive sector. The prospects for connected cars outlined in section 5.3.1 above apply all the more to driverless cars. Optimised traffic flows, enormous safety gains, optimised (intermodal) routes, improved allocation efficiency, spared resources: all these and many other improvements would be made feasible by autonomous vehicles. A huge sphere of possibilities for mobile services would emerge, ranging from the driverless taxi that is hailed and directed by an app and the participation of groups (children, the elderly, the sick) that used to be excluded from car traffic in places through to »automobility subscriptions« (comparable with today's mobile phone contracts) under which people buy access rights to transport.[51]

In addition, the driverless car would radically change the interior of vehicles. Whereas vehicles are currently designed around the driver and steering wheel, this would no longer be necessary in the case of a driverless car. Cars would instead be converted into driving spaces in which passengers can pursue other activities. This would turn the car increasingly into a platform for diverse (digital) offerings and services.[52] Starting from ICT offerings and navigation content and services through to entertainment functions, the driverless car would represent a projection screen for countless new offerings and services – the car would become a type of mobile device.

With these developments, the traditional sales pitches of the established automotive industry focusing on factors like engine performance or road holding would become less important. Distinguishing features like those already familiar from the smartphone and computer segment today, such as computing power, operating system, display resolution and user friendliness, would move into the foreground.

5.4 Impact on the automotive industry

What consequences does the conventional automotive industry face from the developments described above, and what are the challenges and future prospects that emerge? The car is the new digital arena. The share of value added in the car is shifting inexorably towards the digital. In other words, software is becoming more important while hardware is losing relevance. This means that the power structures within the automotive market will alter in favour of those corporations that have the capabilities and skills to operate in the digital world. The result is that capabilities like data processing (big data) and interconnection (smart data), digital design, applications and services – and the ability to earn money from it – will be essential for companies to be sustainable. In return, looking forward this means a loss of importance for traditional business models whose primary sales arguments centred on the automotive engineering features of the vehicle (drive, transmission, chassis, etc.).

51 Cf. ebenda; Boston Consulting Group (2015)
52 Cf. BDVW (2014).

Thus, the traditional automotive industry is facing the challenge of adjusting its business models to accommodate the trends of digitisation, requiring them to become digitised themselves and hence to above all target the opportunities in the new markets of the digital world. The competition for system leadership – meaning the ability to set standards – will account for a critical part of the future market position. It is specifically in this point that the way that new competitors from the digital industry are dealt with will be crucial. Although companies like Google and Apple come from different industries than car-making, they do have plentiful capital they can throw about to buy up technical expertise. At the same time, what is far more concerning is that these corporations already know and shape the digital world. They established themselves in the cybersphere long ago and possess countless reams of user data and patterns, which means they know the habits of future consumers. In addition, they already have experience in exploiting smart data for a profit. This knowledge edge will give the newcomers on the mobility market from the internet industry an advantage in the battle for the growing digital shares of the market. These notably software-based market shares will increasingly comprise services, as the mobility market of the future will have to derive its direction of travel from the new digital possibilities and patterns of consumption. This means that the future business models will consist more of providing mobility services and less of selling vehicles. To put it another way, what used to be purely a product market will continuously evolve into a service market. For conventional car-markers, this would provide a rather different perspective on their own revenue models. While the earnings from simply selling cars would tend to fall, a new area of after-sales activities is emerging in return, comprising services that are repeatedly used following the purchase of the vehicle. This might include individualised software packages, for instance, or an update to entertainment services. An early positioning in these market segments is crucial, especially for German car-makers. Domestic manufacturers cover a large part of the highly profitable premium segment in particular, and the quality, sophistication and user-friendliness of the software-based services are set to become increasingly important distinguishing features in precisely the premium segment.[53]

The challenges in terms of new mobility concepts and driverless cars are comparable. Here, too, the point is to shape the norms and standards. Anyone failing to keep up could quickly lose touch. It is not without good reason that the big car-makers have devised and brought to market their car-sharing models over recent years. The data and insights they have gained as a result are of unparalleled value for later mobility services. Besides the pursuit of system leadership, data ownership is set to be a key component of the future marketplace in the case of connected driving as well. The specific question is: Who is permitted to collect and use (for a profit) the data generated on the road and in the car? A conflict is looming with digital giants like Google or Apple over precisely this issue. Should car-makers choose a cooperative approach with better integration of both smartphones and software (such as Apple's CarPlay), for instance, they risk losing data to potential future competitors. If they take a strictly competitive approach, they risk possibly annoying

53 Cf. Roland Berger (2014a).

customers who want to have their familiar software environment available to them in the car as well. The way these risks are assessed, and the potential competition from the digital industry is dealt with, will have a major influence on the future market position.

Digitisation is changing not only the auto industry but also the entire mobility economy. Major risks are set against immense opportunities. Players that position themselves well now and help to actively shape digital change in the mobility sector have the prospect of a lucrative time ahead in the future mobility market.

6 Digitisation and the financial sector

The internet already sent the financial sector into a panic once more than a decade ago. The technical possibilities connected with the internet smoothed the way for innovative business models. Bank customers were given the tools to make themselves independent of conventional banking advice to a certain extent. In the meantime, online banking, consumer finance portals, internet payment services and real-time share prices have become normality for bank customers, without the banking sector being shaken to its foundations as a result.

Yet something like a gold rush is in the air once again. The digitisation of banking activities is expected to produce major upheavals in the financial sector. FinTech, as financial technology is abbreviated, is the word on everyone's lips. Some of the companies that take on the established financial service providers with financial technology are predicted to enjoy massive growth potential. Accenture, a management consultancy, estimates that banks could lose more than 30 percent of their earnings to new competitors worldwide by 2020. The volume of global investment in FinTech firms more than tripled to $12.2 billion between 2013 and 2014.[54]

We have already mentioned in this study that digitisation will, we believe, reach each and every industry in turn. Market observers similarly expect digitisation to gradually affect every area of the financial sector. The consequences for the financial sector may therefore be more serious this time than in the initial phase of internet euphoria.

Payments are generally considered a suitable target for attack by FinTech start-ups. There are already a series of successful examples in this segment of non-banks becoming market leaders. In the process, FinTech firms mostly use the payment infrastructure of banks to peddle their wares.

54 Cf. Accenture (2015).

These companies frequently offer extensions to the portfolio offered by established financial institutions, meaning that cooperation models are likely to proliferate in the future.

The technical possibilities clearly indicate that the development of cashless payments (such as mobile payments) will continue apace. The euphoria has now gone so far that people have started speculating about the end of notes and coins. At the same time, it is less the technical possibilities and more the (monetary) political motives that are driving debate that is currently being held in several countries.[55]

On the lending side, new business activities like »crowdfunding« and »social lending« are emerging on online platforms – generally without the traditional banking sector. Thanks to big data, the conventional lending business is also believed to contain considerable potential. In this context, self-learning algorithms could help to evaluate the creditworthiness of the applicant, for instance. Today there are already FinTechs and banks that check and process loan requests in this way in a matter of seconds and, where appropriate, disburse the loan immediately. The lending business could prove to be extremely lucrative specifically for the major internet firms that possess large volumes of data. These corporations have the reach and awareness in the consumer market required to achieve acceptance. To cite one example, public transport in London and fast-food restaurants recently started accepting Apple Pay as a means of payment.

Trading platforms are also threatening to compete with the established banking sector. But it will be particularly interesting to see whether digitisation will lead to major upheavals in portfolio management. In this context, some providers rely on standardised portfolio management with passively managed funds. It is, however, remarkable that potential is also ascribed to FinTechs in the portfolio management market as financial markets are practically the mother of all big data analyses. Markets in general, and financial markets in particular, have been used for ages to collate the information about an asset spread around the world to form a price. The old truism »The market is always right« is pretty much the big data mantra of the market traders, coined at a time when the world was still largely analogue. The prices on the financial markets condense the knowledge of the entire financial world which no single person alone could ever have to hand. According to the theory of efficient financial markets, it is therefore not possible to systematically outperform the market as a whole with investment decisions. For investors, this implies that they can achieve an average return on investment with no specific knowledge of the capital markets if they buy certificate on the total market (such as the DAX), for instance, and choose not to pick individual assets (»passive investment«). The ensuing debate of whether active portfolio management is beneficial in the slightest has been running for ages. Possibilities for passive investment have similarly existed for a long time. Accordingly, it is worth asking where the advantage of FinTech firms is supposed to be in this specific field. But maybe the point is not that the technology companies can offer better solutions. The aura of the modern is possibly enough to help turn old wine in new wineskins to be successful. More about this later.

55 For more details, see Quitzau (2015).

We would basically like to divide the solutions that the digitisation of banking is yielding into three general categories (overlaps are possible). In this context, it is unimportant whether the solutions come from technology firms not normally associated with the traditional financial sector or whether the established banks develop the new concepts and instruments in-house.

1. ***New offerings:*** The innovations in financial technology are closing gaps in the existing product offerings of financial service providers. These include things like instant payments (payments and transfers in real time), crowdfunding and social lending via online platforms.
2. ***Enhanced products:*** Technical innovations are improving and/or replacing existing product offerings. This includes things like support from online advisory tools for investments. In the extreme case, the retail customer can switch completely to do-it-yourself, provided he recognises and accepts so-called robo-advisors as adequate substitute for retail banking advisors to provide a personal investment strategy in seconds using a few questions about risk propensity and investment objective.
3. ***»Vorsprung durch Technik«** *(»Progress through technology«) alone:** At least occasionally, solutions will also become established that, if anything, represent only minimal improvements (and sometimes even minor deteriorations) compared with the existing offering – facilitated by the enthusiasm of customers for technology. For technophiles, the ability to use a mobile phone to pay at the supermarket checkout may be a revelation. In actual fact, the gain in social benefit compared with payment with cash, debit card and the like is likely to remain extremely modest. The same holds true in online banking, for example, for identification by fingerprint instead of using the conventional PIN/TAN procedure.

Anyone interested in the outlook for banking and wanting to predict future developments should not, we believe, build their arguments around overly strict assumptions about the rationality of customers. We are convinced that the younger generations increasingly demand what is technically feasible and are not primarily driven by whether the innovation in question is necessary at all (or represents an advantage over conventional solutions). Rather, the advertising slogan »Vorsprung durch Technik« seems to act as a guiding principle for the younger generations.

The ongoing success of virtual currencies – at least in the media – is a good example of this. Bitcoins is considered the best known representative of the new »money«.[56] When trying to assess whether Bitcoins or conventional currencies are the better money, it is important to take three functions of money as the basis. From the economic viewpoint, money has three functions; it acts as:

1. A unit of account or measure of value
2. A means of exchange or payment
3. A store of value

56 For more details, see Quitzau/Sonnberg (2014).

US-Dollar/Bitcoin exchange rate

Bitcoins, in July

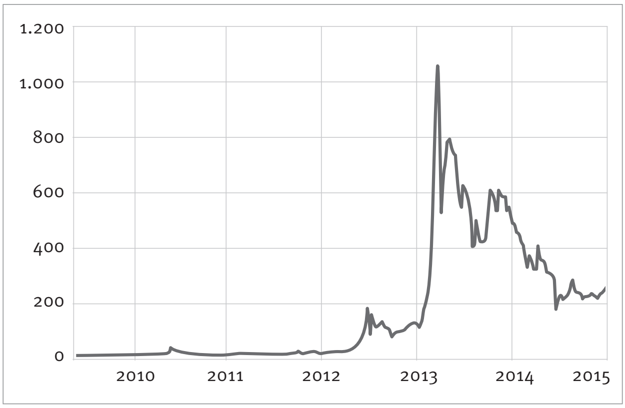

Fig. 11 Source: Bloomberg.

Conventional currencies operate perfectly well as a unit of account and a means of payment. Only when it comes to being a store of value have there been problems since the global financial crisis because the ability of many currencies to retain their value is sometimes doubted. But here in particular, virtual currencies do not represent a good alternative. The massive fluctuations in the price of Bitcoins show that price bubbles can be even greater than with conventional currencies and investment classes. Bitcoins would at best have been only of very limited use as a store of value in the past. The rate for one Bitcoin exploded from $350 to over $1,000 at the end of 2013. Since then, the price has fallen back to below $300 and there have been big swings (see Figure 11).

Bitcoins are unable to shine as a unit of account and means of payment either. The wide price fluctuations have thus far made it impossible to gain a real feel for the exchange rate. Added to this is that no virtual currencies have been recognised as legal tender yet, meaning that no one can be forced to accept Bitcoins or other digital currencies as means of payment. Given this shortcoming, it is amazing that Bitcoins have not long since disappeared from the scene and the media. The only explanation left is enthusiasm for technical innovation.

The established economy will have to become more used to the idea that the success of a given product is often decided solely by its technical sophistication and not primarily the demand. This also holds true for the financial world. Accordingly, we believe the proposition that the financial industry is also facing a digital upheaval is correct looking ahead. Through the pressure they exert on the established financial service providers, technology firms will play their part in ensuring that change will come sooner rather than later.

7 Challenges for economic policy

We prefaced this publication with a quote from the Nobel Prize-winning economist and capital market expert Robert Shiller: »The world is facing massive upheavals. [...] The irony is that people who tried to predict the downfall brought about by automation were always wrong.«

While the quote highlights the immense significance of digital upheaval, it also points towards the economic risks and uncertainties connected with digitisation at the same time. Everyone is talking about the growth potential of the digital economy these days, and the politicians have also finally woken up to the topic. With its Digital Agenda, the German government has sent out a visible signal in an attempt to exploit the opportunities of digital value creation for Germany's benefit.[57] According to the German government, digital change has become one of the key structural challenges for business, academia, society and politics, the opportunities from which it apparently considers far greater than the risks. In view of press reports on the dramatically rising performance capabilities of computers, the economic potential from big data and the (apparently) imminent breakthrough in artificial intelligence, it should come as no surprise if individuals follow the digitisation process with a sense of unease. What the business and working world will look like when the digital upheaval has largely been concluded is almost impossible for even experts to predict. Consequently, economic policy needs to be ready for various different scenarios.

7.1 Scenarios

The conceivable developments can be grouped together to form three scenarios:

1. ***Paradise scenario:*** Technological progress makes human labour almost completely superfluous. A quantum leap in artificial intelligence coupled with the massive use of connected computers and robots in combination with big data make it possible to produce the goods and services that consumers want without human interference. Traditional employment relationships would now be the exception rather than the rule. The scarcity problem would be resolved, scarcity prices therefore superfluous, practically all goods and services would be free of charge. People could do things that they really enjoy. Paradise would be a reality.
2. ***Structural change scenario:*** Business leaders above all view digitisation as merely another phase of far-reaching structural change. Similar to the age of industrialisation, whereas jobs would be destroyed, the released workers would be desperately needed in other areas of the economy. As a result of the technical progress, workers would become more productive and potentially better paid than before. It is already becoming apparent that the digital economy is giving rise to a whole host of new activities. For example, completely new fields of research and employment are emerging for lawyers, sociologists, economists and political scientists as well as IT specialists. The structural change scenario should thus be considered positive as it leads to greater prosperity and those people who are willing to adapt to the changes on the labour market will benefit in the long run.

57 To find out more about the Digital Agenda, please refer to www.digitale-agenda.de.

3. *20:80 scenario:* The third scenario contains elements of the other two. It is conceivable that digitisation will trigger far-reaching structural change under which goods and services can be produced and marketed ever faster – often free of charge. In macro-economic terms, digitisation leads to more growth and greater prosperity. Yet there are serious problems with this scenario. As a result of technical progress, prosperity can be produced by a fraction of the workers required today. There is the risk of a 20:80 society, in which only 20 percent of people willing to work find paid employment and the incomes earned are concentrated among a very small portion of the population (see also the »winner takes it all« argument in section 2.4). This case would be far more than simply a structural change under which everyone can theoretically remain »masters of their own fate«, provided they are only flexible and hard-working enough. Instead, large parts of society would be excluded from the labour market and general prosperity, no matter how willing to work and flexible they might be. The usual instruments of labour market policy would fail, because technological change would destroy the majority of jobs over time and help to create hardly any new ones. There would also not be a level of pay at which it would be theoretically possible to secure full employment.

7.2 Implications for economic policy

In the ***paradise scenario***, the prime function of economic policy would be to ensure that the infrastructure required for the digital economy is available. As soon as digital change has completed and economic paradise is reached, there would be almost no need for economic policy for lack of issues to resolve. That said, though, the paradise scenario will certainly never come to be; it is set to remain utopian, which explains why we will not invest any more time in it here.

In the second and third scenarios, on the other hand, scarcity remains an issue and distribution problems could even worsen. In these cases, politicians and economists would therefore have to look at how digital change is constructed, what a suitable structural and regulatory framework would look like and how rising income inequality could be cushioned by means of redistribution and social policy.

The ***structural change scenario*** is our base scenario (see also section 3). In this case, economic policy would largely be able to operate within the usual bounds. There would be no need to reinvent the wheel. One of the primary tasks of the political establishment in a changing economy is to ensure fair competition. In line with this, the German government's Digital Agenda sensibly aims among other things to facilitate and enable market access for German companies by providing the requisite network infrastructure.

Competition policy would take on special significance in the structural change scenario because companies in the digital economy tend to forge market-dominating positions for themselves. Ambitious start-ups from Silicon Valley frequently aspire to conquer the whole global market immediately (see also section 2). The »winner takes it all« argument lends itself to such immodest goals. Scale and network effects often actually allow first movers to gain a competitive advantage that is almost impossible to recoup. Added to this is the high cost of switching provider on many internet platforms which prevent users from moving to an alternative platform.

Prominent examples like Google and Facebook demonstrate how, while individual companies do not necessarily enjoy a global monopoly, they are certainly able to achieve a market-dominating position in many regions of the world. State regulation may be required to limit the market power that this yields. As simple as this diagnosis might be, appropriate regulation is extremely difficult to put into practice. The business models emerging on the internet are often uncharted waters in every sense of the phrase and they are often impossible to control using the instruments normally applied in the traditional economy. In section 2, we noted the many special features of the digital economy. The task of simply delimiting the relevant market for competition policy is often not easy. Moreover, national or regional regulatory authorities are coming up against global technology firms, which hampers efficient regulation.

Numerous problems are made apparent by the example of the search engine Google. In November 2010, the Directorate-General for Competition of the European Commission opened proceedings against Google covering a total of four allegations of anti-competitive behaviour. Among other things, the EU Commission accuses the firm of using its search engine to distort search results in such a way that its own subsidiaries are preferred. It was precisely with regard to this point that the European Commission sent a statement of objections to Google in April 2015, thus initiating a new phase of the proceedings.

First of all, it is clear that the duration of the proceedings of almost five years now is practically an eternity in light of the technical progress in the internet economy. Accordingly, it is more than doubtful whether answers found today to questions asked in 2010 can claim to have the slightest relevance now. Besides this, Google is by no means a monopoly player in the search engine segment, despite a market share of over 90 percent in many European countries. There are certainly alternatives to Google – for both the customers who use Google as a search engine and the companies that intend to advertise with Google. In addition, it is not even clear whether it is in Google's interest in the first place to prefer its own subsidiaries in the search results, as would appear the case at first glance. This is because Google thrives by providing a first-class service in the form of first-class search results. Pointing people towards its own offerings like YouTube when there are better alternatives available would reduce the number of searches in the long run and hence undermine its business model. These selected examples are intended to convey a sense that the business models of the major internet firms are far more difficult to assess in terms of competition policy than it would appear at first sight.[58]

The main task of the political establishment is to ensure fair competition. Consequently, the regulation of internet firms must not lead to structural change being hindered. Sometimes it is

58 For mored details, see Haucap/Kehder (2013), Haucap/Kehder (2014) or Budzinski (2015).

even necessary to allow monopolies or market-dominating positions at least for a certain amount of time, because this is the only way of achieving the required innovations. The German Minister of Economic Affairs Sigmar Gabriel expressed this in his own words when he said that it is a typically liberal and social-democratic task to restrain and tame untamed data capitalism without robbing it of its ability to innovate and its individual and social benefit.[59]

Even if the digital upheaval were to run as smoothly as outlined in the structural change scenario, it would very probably prove more challenging than past phases of economic change. The speed of upheaval alone would probably be much greater than in the previous industrial revolutions. Economic policy is called upon to implement accompanying and cushioning measures accordingly. State-funded training courses would be needed and flexibility would become top priority for the individual in such a dynamic economic environment. Alongside the politicians, the other stakeholders (such as enterprises and trade unions) would also need to ensure that employees are able to meet the demands of the dynamic economy.

But even if workers are completely willing to adapt to the changes on the labour market and undergo the necessary training, structural change never runs absolutely smoothly. The state must therefore provide financial support and cushion the changes with social policy without quashing the incentives to work in the process. Germany is well-prepared for the upcoming change as a result of the activating labour-market and welfare reforms enacted as part of the Agenda 2010 programme.

The ***20:80 scenario*** is our secondary scenario, with a much lower probability of occurrence than the structural change scenario. Should it come to pass, however, economic policy would have to enter completely new territory. The proven economic regulatory mechanisms would no longer work in this scenario, as they are unable to ensure the necessary balance on the goods and labour markets. Even more than in the structural change scenario, internet giants would be in a position to exploit their market-dominating position. Competition policy would become even more important accordingly.

The actual challenge for economic policy, however, is found in the field of income distribution. Thanks to the highly productive digitised economy, there is no shortage of goods and services. Gross domestic product would be much higher than today. However, 80 percent of the population are excluded from the possibility of earning an income. The remaining 20 percent of the population – entrepreneurs, owners of capital and the remaining employees – would keep the entire value created for themselves. This would be a problem in macro-economic terms, because 80 percent of society would be excluded from any opportunity to consume due a lack of income. Purchasing power and demand would be missing. The economy would dive into a permanent recession in response to the gap in overall demand. Thus, the 20:80 scenario is unstable from the point of view of the economy as a whole.

Much more important, however, is the fact that a large part of the population would find its livelihood withdrawn. A starting point for alleviating material need would be for internet firms

59 Gabriel (2014).

that exploit their customers' data for commercial gain to remunerate such customers for providing the data (see also the box below). Nonetheless, the state would need to come up with a concept for redistributing income to an unprecedented extent – from the entrepreneurs, owners of capital and the few employees to the masses without a job. The state would need to ensure a safety net, perhaps in the form of an unconditional basic income. For the present, when value is (still) created primarily by human endeavour, the concept of the unconditional basic income is inappropriate, as it would reduce or even destroy the incentives to undertake paid work. By contrast, in a world in which only little human endeavour is required to create value, the concept would be an option definitely worth considering for creating a material basis for the whole of society.

Valuable data – Are we selling ourselves too cheap?

The willingness to pay for content online is still low. But even internet offerings are not sure-fire money-spinners. At the very least, the servers on which the page can be reached have to be provided. Plus programmers, designers, editors and office premises are needed as well. All that costs money. And how is completely free content supposed to be funded? The answer: by advertising. The more personalised, and hence the more targeted, the advertising, the greater success and higher earnings it promises.[60] Accordingly, the goal is to offer dog-owners advertising for dog food, while cat-lovers are shown cat litter and cat food. Money can be earned in this way by means of clicks on the advertising. So it should come as no great surprise that firms like Amazon, Apple, Facebook, Google and the like that have possession of huge volumes of user data also analyse data. For some time now, Amazon has shown personalised purchase suggestions in the form of »People who bought this product also bought …«. On 30 January 2015, Facebook even started analysing data generated outside of the social platform.[61] A user ID stored in a cookie is allocated to every user who logs in. When the user then visits other webpages with a Facebook Like button, these pages are stored in the cookie. The aim is for Facebook to know which pages were visited, even if the button is not pressed. The added value from Facebook's point of view is advertising geared specifically to the user: the network could offer advertising for the necessary equipment like clothing and trainers to people who visit pages of fitness studios on the internet.

Box 2

60 Cf. Kurz/Rieger (2011).
61 Cf. ZEIT ONLINE (2015a).

The underlying system is not new and is found in what are known as tracking cookies. Cookies were originally intended to make surfing on a given website more convenient by saving preferences. Today, however, website operators are joining forces, sharing the information in the cookies and registering visits to other pages by way of embedded banner ads. The advantage for Facebook is that the social platform's thumb is these days found on almost every website, which opens up an inexhaustible source of information.

Researchers at the University of Cambridge and Microsoft Research have calculated the potential slumbering in the evaluation of Facebook Likes.[62] In this context, the researchers' algorithm is capable of predicting the skin colour of the respective Facebook users with a probability of 95 percent and their sex with a scarcely lower probability of 93 percent. In three out of four cases, it also identifies the sexual orientation. As the number of Likes shared increases, so does the recognition rate, and the assessment by the algorithm is generally more accurate than by associates, as a similar study shows.[63] It is possible to monetarise such knowledge not only with personalised advertising but also with things like job-application processes. In a 2012 study, experts trained in psychology analysed Facebook profiles to assess professional performance; the results were validated six months later in a meeting with the line manager. Their analysis was far more accurate in this than normal tests.[64]

Before Facebook went public in May 2012, there were plenty of sceptical voices doubting whether the company would be able to monetarise the data of its users for a profit. Today, the company is worth around €204 billion.[65] The network encompasses more than two billion users, of whom around 1.44 billion were also active per month in spring 2015.[66] Assuming that Facebook can only successfully turn the data of active users into money, this gives rise to a hypothetical value per dataset of €142. This figure is certainly vastly overstated. Researchers at Darmstadt Technical University estimate the value of an average Facebook profile at €40–50.[67] Nonetheless, a 1MB package of email addresses in comparison is only worth an amount of one euro cent.

A few people, like internet pioneer Jaron Lanier who won the Peace Prize of the German Book Trade in 2014, are trying to raise awareness of the market value of personal data. He proposes that a micro-payment system be employed to remunerate users for all the data they leave behind on the internet.[68] It is unclear how this could be implemented. And the study's authors from the University of Cambridge are also highlighting the need to take a new approach to the use of personal data. The algorithms they have made available on their website Apply Magic Sauce[69] make it possible to determine the personal digital footprint.

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Box 2

62 Cf. Kosinski et al. (2013).
63 Cf. Youyou et al. (2015).
64 Cf. Kluemper et al. (2012).
65 Cf. Bloomberg, Facebook company value (obtained on 10 July 2015).
66 Cf. Facebook (2015).
67 Cf. WDR (2014).
68 Cf. Lanier (2014).
69 Cf. http://applymagicsauce.com/. Even the offer to determine the value of personal data has a price in this context. The personal data profile may be used in anonymised form for future research activities.

If Lanier's arguments are to be believed, personal data are sold well below their actual value. In fact, the asymmetric distribution of information between two pages can lead to market failure. Let us assume that the page owner is permitted to analyse customer data in depth. In this case, the provider (page owner) is unable to adequately check the quality of the registered personality profiles. The authenticity of the information is a key factor in deciding how much the advertising industry is willing to pay for the advertising space on the digital platform. If, for instance, someone makes himself older or younger than he really is, personalised advertising becomes less effective, and advertising partners reduce the payment per click on their ad. In reality, the providers employ additional factors to ensure the quality of their data, like network effects or the evaluation of user behaviour on the internet. While it is possible to falsify personal information, personal behaviour and connectivity are not. If, for instance, you are friends with a large number of people who left school in 1984, it is unlikely that you are five years younger than the average for that group. The digital platform is able to determine the user's the actual age with a fair degree of certainty accordingly. At the same time, the providers exploit their monopoly position to depress to a minimum the price they are willing to pay to publish the data.

What the user lacks is the transparency making it possible for him to determine the true value of his personal information. From the provider's viewpoint, it is not economically profitable to explain this to him, especially when the user currently enjoys the content »free of charge«.[70] In addition, the legal framework is not in place. The 1995 directive is largely out of date and allows companies to operate in a grey zone. The EU's proposed General Data Protection Regulation, which is intended to raise lax national standards to a European level, is a first step in the right direction. Furthermore, once it has been clearly defined who is the owner of the personal data on the internet, it will also be possible to trade in the related property rights in the future.

Box 2

70 The income from the rental of advertising space is also used for the technical operation of the social platforms. Thus, free provision generally goes hand in hand with a form of advertising.

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