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EU Monitor

Digital economy and structural change

Digital economics

How AI and robotics are changing our work and our lives

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Developments in artificial intelligence and robotics have far-reaching economic and sociopolitical consequences, with some of them already materialising today. Still, the implications of further progress in these fields are not well understood. What will the impact on human society be if AI at some point even becomes superior in all relevant cognitive, physical and perhaps even emotional capacities?

How will the increased productivity and income spurred by AI, robotics and related technologies be distributed between labour and capital? Fear of massive disruption of labour markets through progress in AI is often countered with the argument that previous technological revolutions always led to the creation of new occupations and tasks, many of which had not even been foreseen. Could this time be different?

If unemployment surges and becomes increasingly structural/technological, it would create large gaps in social provisions and fiscal revenues. Governments would struggle to sustain existing social welfare systems. Could a "robot tax" give governments the financial means to compensate for (mass) unemployment, e.g. through a basic income?

Economies around the world are likely to be impacted differently by the diffusion of AI technologies and robotics. Wealthy industrial countries might increasingly “re-shore” production that, over the last decades, had been outsourced and fostered economic development in lesser developed economies abroad.

Governments might have to assume greater responsibility for navigating the effective transition into the digital world. As the pace of technological change and the related launch of new business models are unlikely to slow, the ability of the state and regulators to keep pace is challenged.

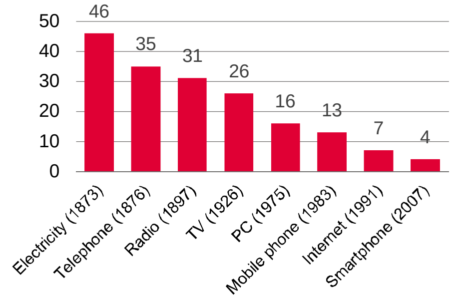
The digital (r)evolution is not constrained to national borders and therefore requires global action. To forge ahead and maximise the benefits for economies and societies, a balance needs to be found globally between successfully promoting key technologies and industries and avoiding the risk of rising protectionism and "knowledge wars".

Future scenarios could be seen as an interplay between speed and scope of technological progress and regulation, where regulation may be considered as manifestation of societal consensus on what technological future we should collectively aim for.

1. The digital (r)evolution

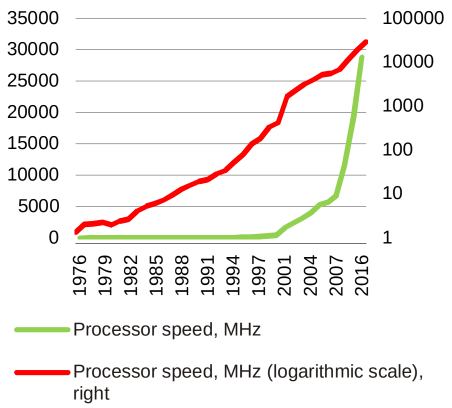
Technology adoption rates speeding up 1

Years until used by at least 25% of the US population



Sources: Federal Communications Commission (FCC), comScore MobiLens, Deutsche Bank Research

Moore's law* and the development of processor speed 2



* Moore's "law", named after Intel co-founder Gordon Moore, in a generalised form states that processor speed will double around every two years (it actually states that the transistor density on a microchip will double every two years). This held roughly true from the 1970s to the 2010s. Over the last years, however, the semiconductor industry started to deviate from the "law" (which was more of a forward guidance) due to physical/technological reasons.

Sources: singulatory.com, Deutsche Bank Research

"It was the best of times, it was the worst of times, it was the age of wisdom, it was the age of foolishness, it was the epoch of belief, it was the epoch of incredulity. ..."

Charles Dickens, A Tale of Two Cities

Ample connectivity, dramatically increased computing power and the spread of portable, multipurpose minicomputers − in a word, smartphones − in recent years have triggered far-reaching societal and economic changes. As a result, the digital transformation has surged to the top of the agenda in business, politics, media and research. The feedback between technological developments and socioeconomic processes is certainly nothing new; in fact, it runs like a thread through human history. Over the last few years, however, the pace of technological development has gained such speed that corporates, consumers and governments often find themselves struggling to keep pace.

Various aspects, technologies and implications of this transformation have been covered extensively, including in our own research, ranging from AI in banking[1], cryptocurrencies[2] and digital cars[3] to robotics and automation[4] in industry and digital policy[5]. At the same time, the broader economic and political implications of key technologies, including those for economic growth, productivity, employment, innovation and the welfare state, have still not been examined in depth. It would be presumptuous to claim to know the trajectory and best policy responses to what might comprise the most formidable challenges and significant opportunities of our times. This paper (and those that follow) therefore hopes to contribute to the ongoing debate by providing some structure to and an overview of the major questions on economists' minds rather than offering simplified answers. Based on the structure outlined below, we aim to publish further reports about the effects of digital technologies on more specific economic aspects in a rapidly changing environment.

Dawn of the digital age – the information explosion

Humans are an adaptable species. It might be our anthropological heritage and evolution due to constantly changing climatic conditions that gave us this remarkable flexibility[6]. In fact, we tend to get used to change so quickly that technology which would have seemed like something straight out of science fiction only a few decades or even years ago becomes a natural part of our daily lives in almost no time − even though most of us would have a very hard time explaining how our high-tech tools actually work. For the last few years, for example, we have been carrying around in our pockets a portable, globally connected and increasingly inexpensive minicomputer more powerful than the entire IT systems used in one of humanity's most daring adventures – the Apollo

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1 Kaya, Orçun (2017). Robo-advice – a true innovation in asset management. Deutsche Bank Research. EU Monitor.
2 Mai, Heike (2018). Why would we use crypto euros? Central bank-issued digital cash – a user perspective. Deutsche Bank Research. EU Monitor.
3 Heymann, Eric (2017). The digital car: More revenue, more competition, more cooperation. Deutsche Bank Research. Germany Monitor.
4 Auer, Josef (2017). Robotics and automation outperform, backed by „Industry 4.0". Deutsche Bank Research. Talking point.
5 Wruuck, Patricia (2015). Updating the single market: Will Europe's digital strategy succeed? Deutsche Bank Research. EU Monitor.
6 Scientific American (2013). Humans May Be the Most Adaptive Species.

Industrial revolutions 3

Industrial revolution (IR)	Period	Transformations and breakthroughs
1st IR	18c	From mostly agrarian economies to industrial ones
		Steam engine, iron works, textile industries
2nd IR	Since 1870s	Expansion of pre-existing industries and new ones, steel, oil, electricity
		Mass production, internal combustion engine, telephone, light bulb
3rd IR Digital revolution	60s until now	From analogue electronic and mechanical devices, to digital technologies
		Microchips, PC, ICT, World Wide Web
4th IR	Currently	Builds on the Digital revolution, new ways to embed technology
		Robotics, artificial intelligence, nanotechnology, biotechnology, IoT, 3D printing

Sources: World Economic Forum, Deutsche Bank Research

program of 1969 that led to humankind's first steps on the moon[7]. Of course, we prefer to use this power to buy things online, stream movies and like our friends' latest holiday pictures than for cutting-edge scientific endeavours.

The process leading to this remarkable spread of information and technology is frequently referred to as the digital revolution. The term describes a major shift from the industrial age to the information age, i.e. a transition towards economies and business models that increasingly rely on information and communication technology and virtual processes rather than analogue mechanics and face-to-face services. The second half of the last century was marked by the upheavals resulting from the development of computer technology. This is often referred to as the Third Industrial Revolution, which was driven by the invention of microprocessors that led to the mass production of personal computers and a rapid increase in storage and computing capacity. Together with the spread of the internet, mobile technology and a drop in costs, it triggered a surge in communication capacities and speed, launching us out of the industrial and into the information or digital age. Exponential growth in data availability enabled rapid progress in machine learning capabilities, in particular with regard to deep learning and reinforcement learning.

This allowed for the development of artificial intelligence (AI) systems for the identification of patterns in large data sets and a broad range of applications, such as speech/natural language processing, computer vision/image recognition (which also serve as the basis for the development of virtual personal assistants such as Alexa, Siri and Cortana), recommender systems (e.g. in search engines and social networks) and predictive analytics[8]. These advancements also supported leaps in a broad range of scientific disciplines that had previously been considered hardly feasible, including genetic sequencing, nanotechnology and the development of human-machine interfaces. The speed with which these radical changes are occurring and their extensive and comprehensive systemic proliferation have become known as the Fourth Industrial Revolution, as popularised by World Economic Forum founder Klaus Schwab.

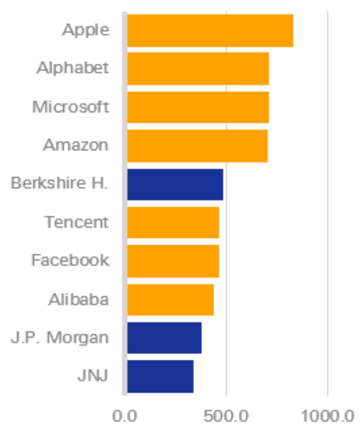
But are we really experiencing a revolution? Just as in evolutionary biology, where long episodes of gradual adjustment can be followed by drastic changes (e.g. the Cambrian explosion 540 million years ago when complex life suddenly emerged in the fossil record), technological and socioeconomic developments might also be understood in evolutionary terms[9]. Often, technologies can exist in principle for decades or even centuries before they lead to a breakthrough. There are various reasons why progress might be hampered. Sometimes, inventions are simply not considered useful; in other cases, their implications and potential applications are not properly understood. In yet another scenario, some key technological components are missing or they are too expensive. Last but not least, the sociopolitical, cultural, demographic, regulatory and economic environment can also disfavour or hinder certain innovations from being widely adopted.

For example, the principle of a rudimentary steam "engine" (the aeolipile) has been known since 100 CE, but a slave-based society of the time, such as the Roman Empire, might not have seen the need or potential for its wider application beyond a technological curiosity. It took until the early 18th century before the first commercial steam engines were developed and as a general purpose technology (GPT) laid the foundation for the industrial age. Analogously, the artificial neural networks behind modern machine learning and AI have been the subject of research since the 1950s. However, they required

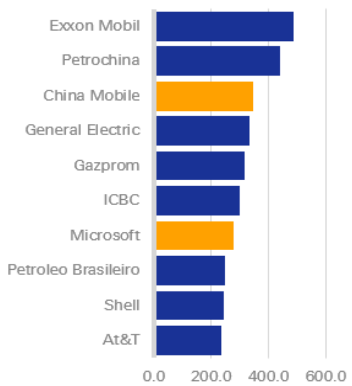
7 Kaku, M. (2011). Physics of the Future.
8 See also Domingos, P. (2015). The Master Algorithm – How the Quest for the Ultimate Learning Machine Will Remake Our World.
9 See also Economist (2014). A Cambrian moment.

World's largest listed companies – techs on the march 4

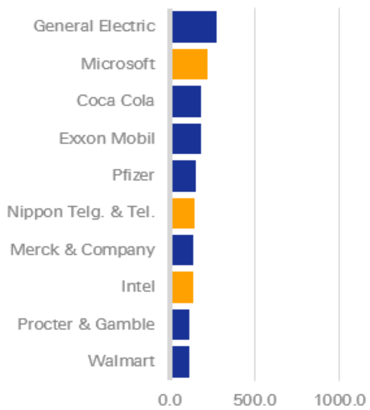
Market capitalisation, USD bn **2018**



Market capitalisation, USD bn **2008**



Market capitalisation, USD bn **1998**



Figures for April 26, 2018, April 25, 2008 and April 25, 1998, respectively.
Note: we use a broader definition of "technology" companies than Thomson Reuters Datastream and include companies for which ICT solutions or digital/platform solutions are at the core of their business model.

Sources: Thomson Reuters Datastream, Deutsche Bank Research

the ability to handle vast amounts of data (i.e. big data) and tremendous (cloud) computing power only in the past few years to allow for the progress in AI development that we are currently witnessing[10].

Of FAANGs, BATs and fake news – a world transformed

Technology is only one side of the story. Increased connectivity and computing power have been equally important, favouring the development of new business models and strategies from the 1990s on, which have both disrupted existing markets and created entirely new ones. They are frequently referred to collectively as the (digital) platform economy. Computer and software standards as well as online services, such as search engines and social networks, benefit greatly from network effects (Metcalfe's law), which describes the increasing value of a service or product by the number of its users. Together with other factors, such as economies of scale and scope, these market dynamics favour the rise of a few dominant superstar firms and might even yield results in monopolies in certain market segments. Microsoft and Apple have more or less shared the market for computer operation systems since the 1980s. The mobile market nowadays is dominated by Google's Android and Apple's iOS.

The undisputed number one search engine in the Western world is Google, while online retail shopping is clearly dominated by Amazon. Together with Facebook, the largest social media platform, and Netflix, which offers online Referred to as FAANG, they are at the forefront of the digital economy. In China, the "Great Firewall" (Chinese internet regulation and censorship) hinders competition with these companies and helps nurture a homegrown digital economy with its own tech giants, particularly Baidu, Alibaba and Tencent (or BATs), that provide services equivalent to their US peers.

For many platform companies (businesses that create value by enabling other users to connect with it through communities or markets and by building on positive feedback between the participants and the company itself), one fundamental aspect of their business model is the exchange of "free" services for user data (e.g. search requests and social contacts). The platform companies can monetise this data, such as through advertisement (two-sided market), and use it to improve their services, thereby strengthening their value and market position. This partly explains the dramatic rise of companies such as Google and Facebook, which together account for more than 60% of global online advertisement revenues, to become some of the world's most highly valued companies within just 10 to 20 years[11].The rise of these companies illustrates how data have become one of the most valuable commodities of the 21st century, which has raised the question of data ownership and privacy to an extent never seen before.

The data scandal surrounding Facebook and the funnelling of user information to the political research company Cambridge Analytica illustrates the far-reaching sociopolitical (and economic) implications. This has contributed to heavy debate on targeted advertisement, manipulation and the spread of false information (as well as the political declaration of facts as fake news) in the democratic decision making process of Western societies. But in a closely connected world, this phenomenon has reached an unprecedented cross-border dimension, leading to increased potential for conflict and tensions on an intergovernmental level.

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[10] Venkatachalam, S. (2017). 2017 is the year of artificial intelligence. Here's why.
[11] Salesforce (2018). Digital Advertising 2020.

Artificial intelligence and machine learning 5

Artificial intelligence	Science and engineering of making intelligent machines, especially intelligent computer programs. It is related to the similar task of using computers to understand human intelligence, but AI does not have to confine itself to methods that are biologically observable.*
Artificial general intelligence (AGI)	Ability to accomplish any cognitive task at least as well as humans.
Strong artificial intelligence	AI system that has mental capabilities and functions that mimic the human brain with no essential difference between the software emulated actions and the actions of a human being.**
Machine learning	Computational algorithms that use certain characteristics to learn from data using a model.***
Reinforcement learning	A machine learning technique in which an artificial agent receives a reward to evaluate its previous action.
Deep learning	A machine learning technique that learns features and tasks directly from data using an architecture of layers of neural networks.
Big data	Refers to voluminous amounts of structured or unstructured data. The increasing availability of digitalised data is a basis for any machine learning application.
Turing test	A practical test for machine intelligence proposed by the famous English mathematician and computer scientist Alan Turing to determine whether a computer can "think". Turing suggested a "The Imitation Game", where a spatially separated human interrogator has to distinguish between a computer and a human subject based on the answers to various questions posed by the questioner. The success of a computer in "thinking" can be measured by the probability of being misidentified as a human.****

Sources: * McCarthy, J. (2017). What is artificial intelligence?
** Tegmark, M. (2017). Life 3.0.
*** Samuel, A.L. (1959). Some studies in machine learning using the game of checkers.
**** Turing, A. (1950). Computing machinery and intelligence.

Sputnik and the ancient game of Go – a global race for AI dominance?

In 1957, when the Soviet Union launched the first man-made satellite into space, the United States experienced what has later been referred to as the "Sputnik moment". Shocked by the technology gap that opened between it and its Cold War rival, and driven by the fear of losing the "space race", the US invested heavily in its own space programme in the following years, sending the first men to the moon only 12 years later. The Chinese government appears to have experienced its own "Sputnik moment" in 2016, when they saw AlphaGo, a machine learning-based AI program designed by UK-based DeepMind (a subsidiary of Alphabet/Google), defeat one of the world's top Go players in four out of five rounds[12]. Go, a game of Chinese origins which is over 2000 years old, is highly popular across Asia. Due to its computational complexity, Go has been considered much more difficult for artificial intelligence to master than chess, for example. In 2017, a second version of the program called AlphaGo Zero surpassed its predecessors in just 40 days through reinforcement learning by only playing against itself and without any data sets of previous games provided by humans[13].

In the same year, China outlined a bold multi-billion national strategic plan to catch up with global AI research by 2020 and to deliver major breakthroughs and reach world-leadership in AI both for civilian and military applications by 2030. While the race for AI leadership is considered to be mainly decided between the US and China, other countries are not planning to stand idle at the side lines to watch. Russia's President Vladimir Putin called AI "the future" and even warned that "whoever becomes the leader in this sphere will become the ruler of the world"[14]. 25 EU countries signed a declaration in April to join forces and to engage in a "European approach" to AI, including funding for both research to harvest the potential of artificial intelligence as well as also to address the implied challenges and threats[15]. Increasing concerns about military applications of AI motivated more than 100 representatives of AI and robotics companies from 26 countries to send a joint letter to the United Nations calling for the ban of lethal autonomous weapons, a step that major developers of autonomous systems including the US, UK, China and Russia oppose. One of the signees is Tech entrepreneur Elon Musk (Tesla, SpaceX) who had also warned that "competition for AI superiority at national level" might go as far as triggering a global war[16].

One does not have to contemplate gloomy military scenarios in order to recognise the perceived sense of urgency and potential for rising conflicts and tensions related to AI and robotics. A current draft of EU legislation for intensified screening of foreign investment "on grounds of security and public order" is targeted in particular at Chinese investments in strategic sectors. In addition, the current economic dispute between the US and China goes far beyond trade, including US restrictions on Chinese investment related to China's intellectual property practices.

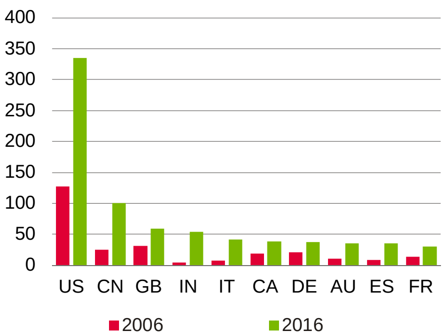
This time is different? Cyber-utopians and digital doomsayers

Researchers, companies and governments agree that developments in artificial intelligence and robotics have far-reaching economic and sociopolitical

[12] See New York Times (2017). Beijing Wants A.I. to Be Made in China by 2030.
[13] See DeepMind (2017). AlphaGo Zero: Learning from scratch.
[14] CNN (2017). Who Vladimir Putin thinks will rule the world.
[15] European Commission (2018). Cooperation on Artificial Intelligence.
[16] The Guardian (2017). Elon Musk says AI could lead to third world war.

Top-cited scientific papers related to machine learning 6

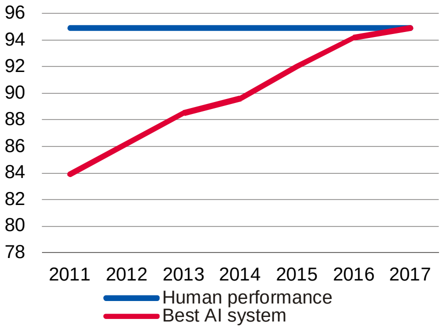
Papers among among the 10% most cited



Sources: OECD calculations based on Scopus Custom Elsevier and 2015 Scimago Journal Rank from Scopus journal

AI reaches human-level speech recognition abilities 7

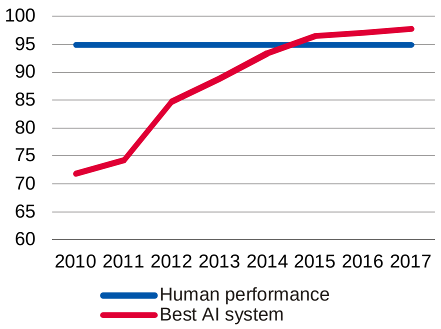
Speech recognition (Switchboard HUB5'00), accuracy, %



Performance of AI systems on a task to recognize speech from phone call audio; Word Error Rate (WER) of trained speech recognition systems on Switchboard Hub5'00 data.
Sources: Artifical Intelligence Index, Electronic Frontier Foundation, AI Progress Metrics

AI outperforms humans in object detection competition 8

Object detection (LSVRC), accuracy, %



Performance of AI systems on the object detection taks in the Large Scale Visual Recognition Challenge (LSVRC) competition.
Sources: Artifical Intelligence Index, image-net.org

consequences, with some of them already materialising today. However, no one knows what exactly lies ahead of us. The history of predicting future technological and societal developments shows a rather mixed track record, particularly with regard to long-term projections. When it comes to artificial intelligence, the debate is divided broadly along two lines. The first one concerns the speed and overall potential of developments. The question here, in other words, is when – if ever – could human-developed AI reach and eventually exceed the level of human intelligence (referred to as artificial general intelligence/ AGI, sometimes also as strong AI)? Could we even reach a point when AI becomes so powerful that it abruptly triggers a chain reaction of self-improvement and “runaway” technological growth, leading to an intelligence explosion with unknown consequences? Posited as a technological singularity, this controversial hypothesis has famously been popularised by inventor and futurologist Ray Kurzweil[17].

The second line of debate pertains to the consequences. What will the impact on human society and humans’ understanding of themselves be if AI becomes superior in all relevant cognitive, physical and perhaps even emotional capacities? MIT physicist Max Tegmark[18] groups the discussants within the following categories: “techno-sceptics” who doubt that superhuman AI might appear within the next 100 years or so; “digital utopians” who think that a breakthrough from narrow AI (e.g. task-specific algorithms trained to solve narrowly defined problems) to general AI applications might well happen within a few decades and will benefit mankind on the whole (some members of this group see the rise of general AI as the next logical step in evolution, whereby humans will increasingly augment and upgrade their abilities through technology and at some point even merge physically with their machines − some claim that this is already happening, as illustrated by the smartphone as a powerful extension of our abilities to communicate, memorise etc.); “luddites” who share the utopians’ time horizon, but who are highly concerned about the outcomes; and a “beneficial AI movement”, a group of researchers who also think that the option of achieving superhuman AI within the next few decades should not be disregarded, who acknowledge the opportunities and potential of powerful artificial systems, but who also strongly urge taking precautions and defining global standards to ensure that humans will not lose control of their creations. To be sure, differences in this debate are not just between a group of experts and the wider public, but actually within the AI community itself.

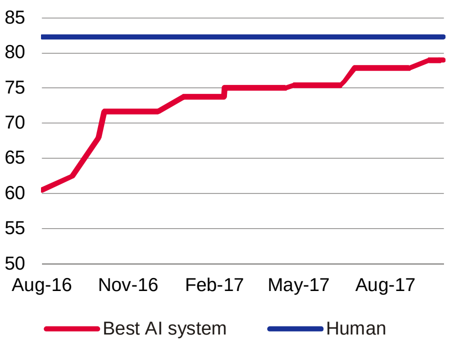
When it comes to artificial intelligence, two parallel debates that are strongly related, but not exactly the same, are often intermingled. The development of superhuman artificial intelligence, which may rightly be the most important moment in human history, might still be very far away or it may never come at all. However, this does not mean that rapid progress in the development of AI, whether “narrow” and task-specific or in the form of increasingly advanced and adjustable AI systems for multipurpose applications, would not have a far-reaching impact on our social and economic reality.

In many fields, machines are already far more advanced than humans, whether it involves computational tasks, memory or recently a rapidly growing field of pattern recognition activities[19]. Still, the consequences of further progress in these fields are not well understood. Fear of massive disruption of labour markets through progress in artificial systems is often countered with the argument that previous technological revolutions have been accompanied by the same concerns, but always led to the creation of new occupations and tasks, many of which had not even been foreseen. Proponents argue that the

17 Kurzweil, R. (2006). The Singularity Is Near.
18 Tegmark, M. (2017). Life 3.0.
19 See AI 100/Stanford AI Lab (SAIL) (2017). AI Index – 2017 Annual Report.

AI catches up in Question Answering (SQuAD) 9

"Excact match" with answers in the test set, %

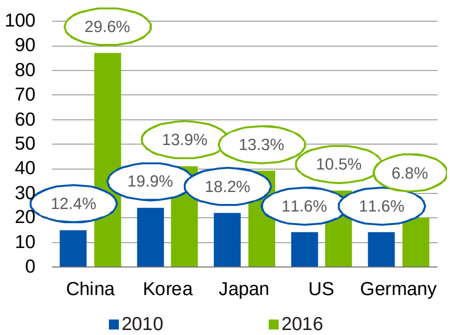


Stanford Question Answering Dataset (SQuAD), dataset with over 500 articles and 100,000 question-answer pairs; task: identify answer to a given question within the article.

Sources: Artificial Intelligence Index, stanford-qa.com

China drives global increase in industrial robots supply 10

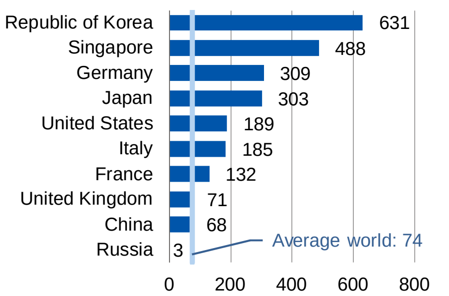
Est. annual supply of industrial robots, thsd. units and (% of global)



Source: International Federation of Robotics

Most robotized industries in developed Asia, Germany, US 11

Industrial robots per 10,000 employees in manufacturing 2016



Source: International Federation of Robotics (IFR)

same thing is likely to happen this time as well. Humans might find new and more satisfying occupations and, by receiving education and upgrading their digital and interpersonal skills, supported (or augmented) rather than replaced by AI, remain competitive participants of the economy. Critics of this view respond that in the past, mainly manual and hard or standardised physical labour as well as linear computational tasks were replaced by machines. They claim that this time it could be different, as the whole range of cognitive abilities might be rivalled by AI and potentially lead to mass unemployment. From a more positive perspective, it might also enable us to live a comfortable life without depending on work.

Unlike other pressing issues such as climate change, where there is a majority consensus (it is taking place, (mainly) caused by human activities and will have more negative than positive consequences) standing opposite a sceptical minority, there is little guidance when it comes to the consequences of digital transformation, robotics and AI. We earlier described humans as an adaptable species, and humankind's adjustment over the last few centuries to a dramatically changed environment certainly supports this point. Several questions remain, however: To what extent, individually and collectively, do we find ourselves capable of adjusting and actively shaping the current technological upheaval rather than being driven or even overrun by it? And to what extent can we muster the strength to cope with increasing demands on our adaptability?

2. Digital economics

When we talk about the impact of the digital revolution and, in particular, AI and robotics on the economy, it seems important to stress one point right from the outset: During the last two hundred years since the spread of the steam engine, continuous technological progress has been one of the main drivers of economic growth and prosperity, providing us with (exponentially) increased power (energy), productive means, mobility and organisation/communication. This has allowed us to provide products and services in ever greater quantities and quality at lower costs[20].

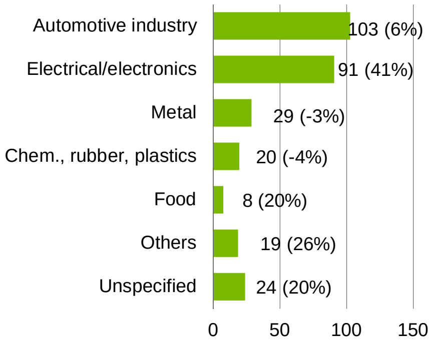
Of course, this development has come at a price, such as ecological damage and a changing climate, as well as fundamental technological risks, such as the potential for global nuclear destruction. These "side effects" certainly need to be taken into account when assessing the (global) economic welfare and accumulated added value of technological progress over time. From an economic perspective, further technological advancements – in particular related to AI and robotics, but also in other (cross-pollinated) fields, such as 3D printing, nano- and biotechnology – should in principle have a highly positive impact. Technology might even help us address the collateral damage to the environment caused by the dramatic economic expansion of the last two to three centuries, by spurring research into renewable or low-carbon energy sources or even geoengineering, for example.

This kind of technological progress, its velocity and the breadth of its socioeconomic implications are best described by Schumpeter's concept of "creative destruction"[21]. However, it is far from clear if the overall impact of the next technological leap(s) will be seen as positive, whether on an individual or societal level. How will the increased productivity and income spurred by AI, robotics and related technologies be distributed between labour and capital, i.e.

[20] See also Brynjolfsson, E. and A. McAfee (2014). The Second Machine Age.
[21] Schumpeter, J.A. (1942). Capitalism, Socialism and Democracy.

Industrial robots mainly in automotive, electronics industries 12

Annual supply of industrial robotics, worldwide 2016, thsd. and (Change from 2015 to 2016)



Source: IFR World Robotics 2017

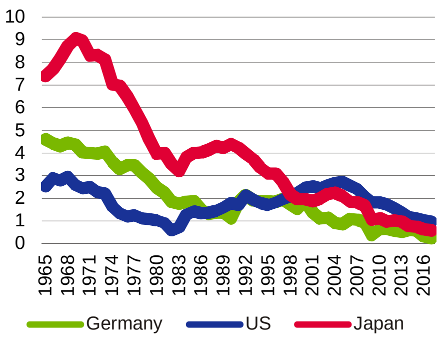
Average US quarterly labour productivity (LP) growth by period 13

Period	Avg. LP growth qoq (%)	Ann LP growth (%)
1947-1973	0.7	2.8
1974-1994	0.4	1.5
1995-2004	0.7	2.9
2005-2017	0.3	1.2

Sources: Bureau of Labor Statistics, Deutsche Bank Research

Labour productivity (per person) 14

%-growth (10-year moving average)



Sources: The Conference Board Total Economy Database™, Deutsche Bank Research

between (potentially superfluous) workers/employees, on the one hand, and the owners of technology on the other? How differently will it affect high-skilled and low-skilled workers? In the future, will we all live in a "leisure society" where machines provide us with the means for living? Or will technological progress lead to increased inequality, mass unemployment and impoverishment? How would such a scenario affect the underlying political systems, the role of governments and the welfare state? These are some of the questions that we want to shed light on in this and upcoming publications. The spread of technological benefits certainly does not follow a predetermined trajectory or natural law. In light of increasing automation and abundance, it comes down to a collective choice – at least in democratic societies – of what kind of society we want to live in.

The future of growth – production, robotics and AI

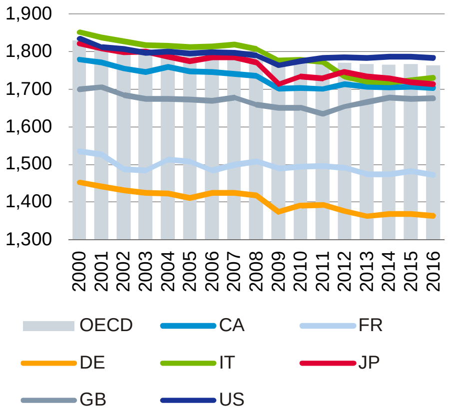
There are three main drivers of economic growth: (1) increases in the stock of capital with (2) technological progress embodied in new capital equipment, (3) growth in labour input and human knowledge, acquired from education, research and development. The impact of digital technologies on the economy and on productivity growth in particular is subject to controversial debate[22]. The 1980s saw the introduction of the PC, followed by constant growth in the availability of digital information and reduced search costs thanks to the spread of the internet. At the same time, countries at the forefront of the digital revolution, most notably the US (2.8% yoy growth on avg. from 1995–2004), experienced growth rates in GDP and productivity that hardly anyone expected in the '80s and early '90s[23]. But as the productivity gains from the ICT boom largely eroded, productivity growth slowed to 1.9% in the pre-crisis years (2004–2007). While the recession led to a rebound in the period from 2008–2010, the following years were plagued by disappointing labour productivity growth, triggering a revival of the debate over "secular stagnation". Since 2011, US labour productivity has grown on average by 0.5% per year.

This development is best described by Robert Solow's famous quote about the so-called productivity paradox: "You can see the computer age everywhere but in the productivity statistics"[24]. One explanation offered for this phenomenon is that the full potential of technology to bolster productivity materialises only gradually as innovation takes time to fully diffuse into the economy[25]. A question of crucial importance therefore is whether the recent slowdown in productivity growth will be overcome, by a strong positive impact from artificial intelligence and, if so, how workers will fit into such a scenario. Accenture (2017) forecasts a doubling of annual US GDP growth up to 4.6% by 2035[26]. McKinsey estimates that automation will boost global economic growth by annual gains of 0.8 to 1.4 pp through 2065[27]. This would be roughly equivalent to an additional 1.1 billion to 2.3 billion full-time workers. As a result, the dampening growth effects of shrinking labour forces due to the demographic transition in the industrialised would at least be offset. These projections are certainly based on some strong core assumptions (e.g. Accenture assumes that AI will constitute an additional factor in production alongside labour and capital and that AI will not substitute,

[22] Oliner, S.D., D.E. Sichel and K.J. Stiroh (2007). Explaining a Productive Decade. Jorgenson, D.W. and K.J. Stiroh (2002). Raising the Speed Limit: U.S. Economic Growth in the Information Age.
[23] See also Syverson, C. (2017). Challenges to Mismeasurement Explanations for the US Productivity Slowdown.
[24] Solow, R.M. (1987). We'd better watch out.
[25] Brynjolfsson, E., D. Rock and C. Syverson (2018). Artificial Intelligence and the Modern Productivity Paradox: A Clash of Expectations and Statistics.
[26] Accenture (2017). Why Artificial Intelligence is the Future of Growth.
[27] McKinsey (2017). A future that works: Automation, employment, and productivity.

Hours worked per person have trended down in major advanced economies 15

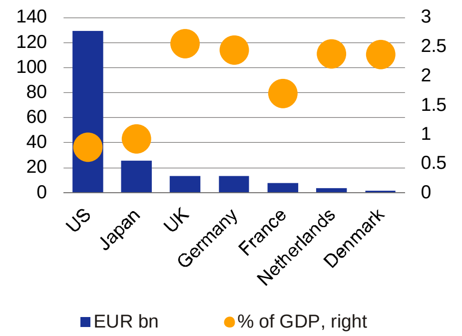
Average annual hours actually worked per worker per year (total employment)



Source: OECD

Data as the new commodity 16

Trading volume of products and services based on data and information (2016)



Sources: iwd based on Eurostat, International Data Corporation

but rather augment labour, i.e. labour will remain constant). These rather optimistic scenarios form an alternative to the hypothesis of secular stagnation[28].

Economies around the world are likely to be impacted differently by the diffusion of AI technologies and robotics. Some believe there is a risk that wealthy industrial countries might increasingly "re-shore" production that, over the last decades, had been outsourced and fostered economic development in emerging markets and lesser developed economies abroad. Advances in technologies such as 3D printing might allow companies in industrialised countries to produce at home at competitive costs, marking a new wave of capital deepening. For emerging markets, this could involve the risk of falling behind or not catching up with industrial countries as quickly as hoped. Or 3D-printing might allow startups and small entrepreneurs in emerging markets to "leapfrog" traditional manufacturing methods and "circumvent supply chain infrastructure limitations"[29].

Data economy – what are we measuring, exactly?

The concept of measuring value added is at the core of macroeconomics. With the increasing importance of the digital sector, however, standard measurement metrics such as gross domestic product (GDP) have come under increased scrutiny. In order to determine the contribution of a product or service to GDP and therefore to economic growth, we need to know its quantity and market price. But many of the core products provided by digital (platform) companies, such as messaging services, social networks, search engines or maps, are provided free – at least when measured in monetary terms. Somehow they are still being "paid" for, however, as illustrated by the high stock market valuation and revenues of big techs. In what is frequently referred to as version of a "two-sided market", users "pay" for a service by providing their data, which platforms can monetise by selling (targeted) advertisement space on the other side of that market as well as use to improve its own services. One side of this market (i.e. users of "free" services) may be better described in terms of a barter rather than a money-based economy, which clearly makes it difficult for economists to measure these services' contributions to standard measures of welfare[30].

Wikipedia, YouTube etc. clearly provide value to millions of users, but how does one measure this value[31]? Does an increasing share of these free services and interactions lead to a "measurement error"? Some see this as one of the potential factors explaining the discrepancy between the technological progress achieved and the slowdown in productivity growth described above. Measuring the value of free goods and services breathed new life into what is known as the "mismeasurement hypothesis" of productivity. The issue of correctly measuring CPI and thus determining the GDP deflator within the context of ICT progress was prominently discussed by the Boskin Commission in the late 1990s.

However, according to the IMF, the "digital sector" currently still contributes less than 10% in most economies, "measured by value added, income or employment". For the US, the "undermeasurement" of US labour productivity growth is below 0.3%, which puts it below the slowdown in productivity growth observed since 2005 by around 1 to 2%[32].

28 Gordon, R.J. (2015). Secular Stagnation: A Supply-Side View.
29 OECD (2017). The next production revolution - Implications for Governments and Business.
30 See also Financial Times (2018). How Big Tech brought back the barter economy.
31 See also Brynjolfsson, E. and A. McAfee (2014). The Second Machine Age.
32 IMF (2018): Measuring the Digital Economy.

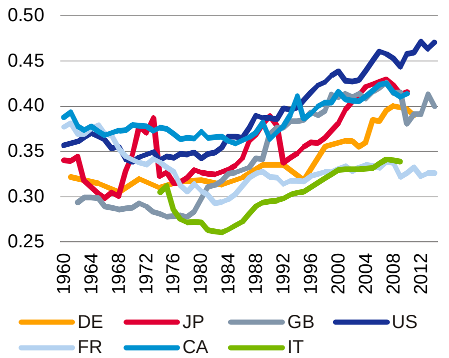
Substitutability potentials in Germany 17

Study of:	2013	2016
Helping profession	46	58
Skilled occupation	45	54
Specialist professions	33	40
Expert occupations	19	24

Source: Dengler and Matthes (2018)

Pre-tax national income held by the top 10% share in major advanced economies 18

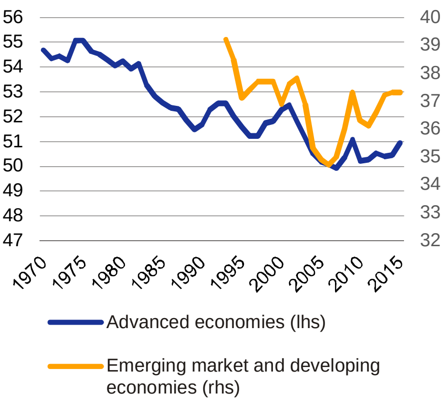
Percentile



Source: World Inequality Database

Share of national income paid to workers 19

Labour share of income in %



Source: IMF, World Economic Outlook, April 2017

I, Human. Labour markets and the future of work

Since time immemorial, livelihood has required people to work. At least collectively, the rule has always been that there is “no such thing as a free lunch”. The search for ways to make labour use more efficient is just as old. Technological progress, changes in the organisation of working life and their impact on social coexistence have always been part of human existence. Change requires time and energy. But as long as people can keep pace and enjoy the fruits of their own efforts, they will not perceive technological change as a threat. An extreme disturbance to these conditions, however, harbours the risk of social discord.

Today, labour is still a key input factor in the value creation process in our economies and hence promises each member of society a chance to maintain his or her relative position or to climb the income ladder through education, qualification and hard work. The current digital transformation of the “second machine age”[33], with its exponential diffusion of technology, its speed and its combinatorial effects on the world of work, could disrupt labour markets on an unprecedented scale and reduce or even marginalise the importance of labour input (for the production of goods/services). That technological upheavals change physical work and replace human labour through machines is not a new phenomenon. What is new, however, is that cognitive activities are increasingly subject to automation as well. Until recently, the standard assertion was that automation poses a significant threat primarily to “simple routine tasks”. But this could turn out to be a fallacy today, and some people have already begun warning that, at some point, all algorithmic and highly routine-heavy activities are likely to become increasingly suitable for automation. This includes, for example, diagnostic routines of doctors to tasks of tax inspectors and lawyers. In some scenarios, artificial systems might catch up with or exceed human capacities even in non-routine tasks that require creativity, the application of the scientific method or strategic planning.

Such scenarios imply the widespread automation of the economy where AI − rather than humans − becomes the major factor driving innovation and growth. Even highly educated and skilled workers might have a hard time finding a job, and companies would rely almost entirely on capital (e.g. machines, robots and AI)[34]. If it is possible to increasingly automate cognitive activities, could it be that professions with real interpersonal interaction would be less affected by technical substitution? Measured in terms of their remuneration, however, these occupations (e.g. nursing and social work) currently tend to fall in the lower-wage range. This raises the question of whether their social recognition and status might change when highly qualified activities, such as medical diagnoses, are taken over by algorithms. Studies on the impact of investments in new technologies generally show strong polarisation effects[35]. In Germany, for example, employment and wages in high-wage occupations have risen disproportionately in the past five years compared with medium- and low-wage jobs and sectors[36].

The breadth of digital transformation adds a whole new dimension to the pressure to adapt to labour as a production factor. This is perceived by many people as a serious threat to their earned income. Unsurprisingly, the question of labour’s future share of income has taken centre stage in the debate on the digital future. Will the current technological change turn out to be inclusive (i.e.

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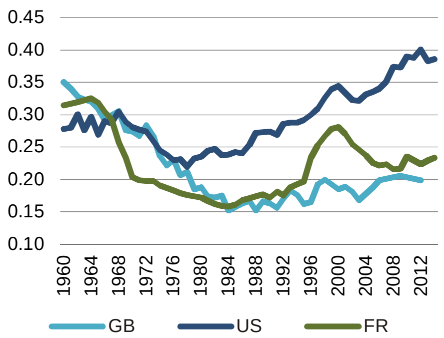
[33] See also Brynjolfsson, E. and A. McAfee (2014). The Second Machine Age.
[34] See also Sachs, J.D. (2018). R&D, Structural Transformation and the Distribution of Income.
[35] Frey, C. and M.A. Osborne (2013). How Susceptible are Jobs to Computerization.
[36] Arntz, M., T. Gregory and U. Zierahn (2018). Digitalisierung und Zukunft der Arbeit – Makroökonomische Auswirkungen auf Beschäftigung, Arbeitslosigkeit und Löhne von morgen.

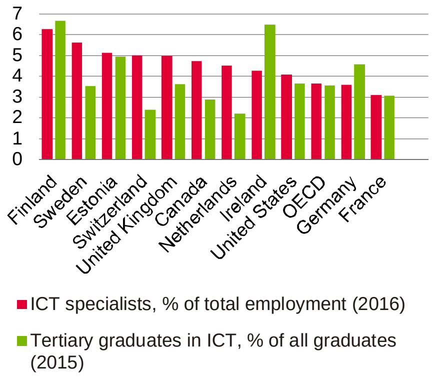
Net personal wealth held by the top 1% share 20

Percentile



Source: World Inequality Database

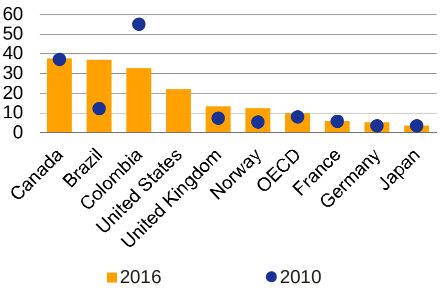
ICT in employment and education 21



Source: OECD

Individuals who attended an online course 22

As % of individuals who used internet in last 3 mon



Source: OECD

the majority will profit or at least not be worse off) or exclusive (a minority of capital owners and professionals will reap most/all of the benefits)[37]? Will the Fourth Industrial Revolution destroy more jobs than it creates and maybe even lead to structural "technological" mass unemployment, a drastic increase in income and wealth inequality, as well as in social and political instability? While it is certainly very difficult to anticipate the impact of technological change on job markets over the coming decades, several research papers published in recent years have tried to give some guidance. In 2013, Frey and Osborne from Oxford University saw around half of US jobs at risk of automation[38]. In 2016, Bank of England's chief economist Andy Haldane gave a similar figure for the UK[39]. For Germany, current studies arrive at differing results. The range extends from 42%[40] of activities subject to social security contributions which could be replaced by computers in the next 10-20 years to a more optimistic 15%[41]. What most studies have in common is the assumption that this adjustment process will be slow, but marked by strong structural changes.

The question therefore arises how workers need to be trained and, above all, further qualified so that they can cope with this change. Ultimately, society must also discuss how to support people who have been eventually forced out of the labour market by algorithms and robots.

Race against – or with – the machine? AI and education

There is no doubt that the rapid diffusion of AI and robotics in work processes and industries will spell widespread and, in some cases, dramatic implications not only for the labour market as a whole, but also for each individual worker and market participant. In the digital age, the term "VUCA" − which stands for volatility, uncertainty, complexity and ambiguity, and was originally used to describe the state of the world at the end of the Cold War − has acquired a new facet. AI and robotics are likely to replace or augment human labour in a widening range of tasks and professions. For students, pupils and their parents, decisions about what to learn and how to invest time and money in skills and knowledge will become increasingly difficult. Due to technological change, skill profiles will certainly be changing as well, often repeatedly. However, it might be easier to anticipate which jobs or tasks could be replaced or augmented in the near future than to predict what kind of knowledge and skills will still be relevant in 10, 20 or 30 years, especially as some of the leading industries of tomorrow might not even exist yet. Is it therefore advisable, for example, to prepare for tasks that require ICT and programming skills – even though AI systems might become increasingly self-improving? Or is it more prudent to bet on tasks that require social skills and empathy – even though AI systems might also take over more responsibilities in social services such as elderly care?

It seems that technological advances will demand unprecedented flexibility when it comes to education and learning. Importantly, rapid changes to the work environment and requirements of the labour market will make it necessary for participants to engage in lifelong learning, to upgrade their skills and to retrain throughout their work life, which applies as much to teachers as it does to students. The changing work environment will require the educational system to change as well. Knowledge of natural, social and business sciences might still have job market value in the future and demand for analytical and ICT skills can

[37] See also Korinek, A. and J.E. Stiglitz (2017). Artificial Intelligence and Its Implications for Income Distribution and Unemployment.
[38] Frey, C. and M.A. Osborne (2013). How Susceptible are Jobs to Computerization.
[39] Haldane, A. G. (2015). Labour's Share.
[40] Bonin, H., T. Gregory and U. Zierahn (2015). Endbericht Kurzexpertise Nr. 57.
[41] Dengler, K. and P. Matthes (2015). Folgen der Digitalisierung für die Arbeitswelt: In kaum einem Beruf ist der Mensch vollständig ersetzbar.

Core skills for employment in the upcoming AI era* **23**

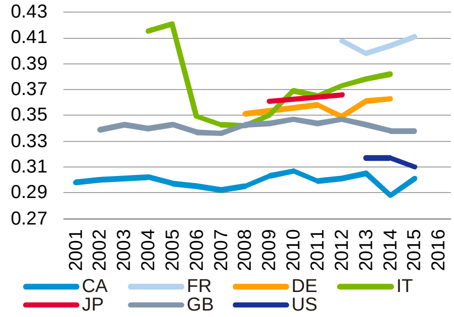
"Type I" analytical, creative, adaptive	- critical & creative thinking - analytical & research - sense-making - novel adaptive thinking - design mindset
"Type II" interpersonal, communication	- effective communication - interpersonal abilities - social intelligence - virtual collaboration
Type "III" emotional, self confidence	- self-awareness - empathy - coping with stress - manage cognitive load - coping with emotions

* based on skills sought for employment from internet sites

Source: Trajtenberg, M. (2017). AI as the next GTP: a Political-Economy Perspective

Poverty ratios in major advanced economies before ... **24**

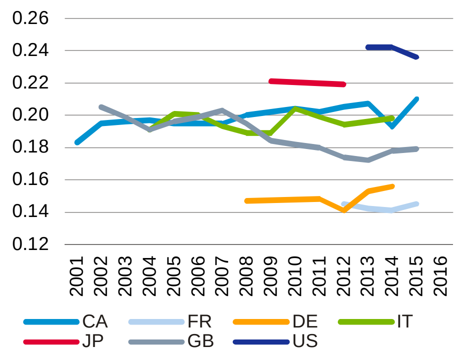
Poverty rate before taxes and transfers, poverty line 60% (new income definition since 2012)



Source: OECD

... and after fiscal redistribution through taxation and transfers **25**

Poverty rate after taxes and transfers, poverty line 60% (new income definition since 2012)



Source: OECD

be expected to remain high. However, general abilities such as creativity, critical thinking, I, Human. Labour markets and the future of work effective communication might become (at least) equally important to maintain a competitive edge[42].

Parents, schools and universities will therefore increasingly be called on to foster students' and children's cognitive, artistic and interpersonal skills through personalised and adaptive learning approaches. AI-driven educational software and intelligent tutoring systems might be increasingly employed to this end, as they could allow for tailored content and learning techniques based on students' individual abilities, learning pace and personality. Online training options such as massive open online courses (MOOCs) and nano-degrees, often offered by leading universities for free or at a fraction of the on-campus tuition fees, might grow in importance. And as education finds itself competing for students' attention with a multiverse of virtual content and distractions, it will increasingly need to develop new educational strategies that mimic the success formula of the attention economy, for example by merging learning with playing (gamification).

Finally, pupils and students increasingly find themselves exposed to an overload of – often unverified and intentionally manipulative – information as well as to a cornucopia of apps and services that use sophisticated psychology-based "persuasive technology" in order to maximise users' attention and engagement and that might even lead to addiction[43]. Children and young students therefore need to learn "digital media literacy" skills from an early age in order to use digital technology responsibly and safely and to foster their ability to critically reflect on media content and their own usage of it.

Towards a digital social contract? Technological unemployment, taxes and the (welfare) state

What are the socioeconomic implications if the digital pessimists' belief that automation and AI will lead to technological mass unemployment in the not-so-distant future and depress the wage share in national income were to become a reality? If unemployment surges and becomes increasingly structural[44],it would create large gaps in social provisions, as they mainly depend on employment and labour income, which would fall substantially in such a scenario.

Governments, particularly those in wealthy, Western-type social market economies, would struggle to sustain the current size and generosity of existing social welfare systems, as they would simply lose their fiscal power (space) and become incapable of mitigating primary market income inequality through fiscal redistribution (e.g. through progressive income taxation as well as public spending on education, health and pensions). In major advanced economies poverty rates after taxation and transfers tend to much lower than before fiscal redistribution, according to data from the OECD. In such a "jobless" world, financially weakened governments would certainly be forced to cut their social spending drastically and ultimately lose control of social policies – unless they find reliable alternative sources for collecting revenue. If governments failed to mitigate the socioeconomic downsides of such a trajectory through appropriate safeguards, it would likely result in a drastic rise in income, wealth and social inequality. This has triggered a heated debate on adequate responses by

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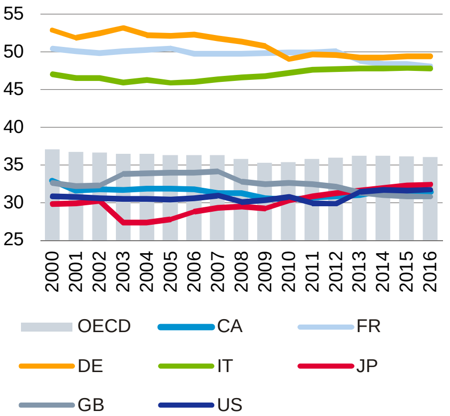
[42] Trajtenberg, M. (2017). AI as the next GPT: a Political-Economy Perspective.
[43] See also Wired (2018). Guide to Internet Addiction.
[44] Keynes, J.M. (1930). The Economic Possibilities for Our Grandchildren. Keynes saw "technological unemployment" as a "temporary phase of maladjustment" before "mankind is solving its economic problems".

Tax wedge on labor income is especially high in Western European countries 26

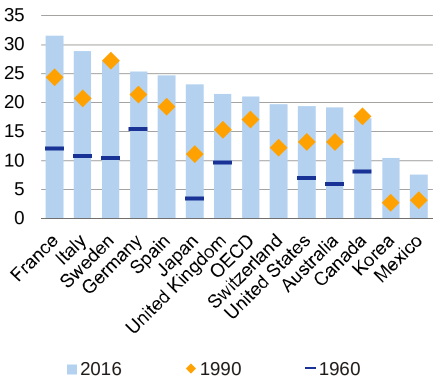
Average tax wedge of a single person (&) (100% of avg. earnings, no child)



Sources: OECD, Deutsche Bank

Public social spending is today much larger compared to a couple of decades ago 27

Public social spending, % of national GDP



Source: OECD

governments, which, at their core, usually focus on taxes on robots, machines and AI and/or the introduction of a universal basic income.

Governments could aim to restore their fiscal space by moving towards greater taxation of capital income, wealth (on financial or real estate assets), value creation and/or consumption of such items as luxury goods. Still, in order to be successful, governments around the globe would likely need to secure a high level of tax coordination and cooperation amongst themselves, as wealthy individuals and multinational corporations might try shifting income to low-tax destinations[45]. One alternative would be the introduction of a “robot tax”, such as the one propagated by Microsoft founder Bill Gates. It could be implemented as a special corporate tax linked to the usage of robots/machines and AI in the value creation process[46].

Alternatively, it would be possible to tax a corporation’s cost savings/profit gains due to the substitution of human labour. This new tax could make up for the (potential) loss in any labour income taxation and publicly collected social security contributions and help mitigate/offset the social costs caused by automation’s displacement effects in the labour market. It would also change the relative prices between the input factors of labour and capital (e.g. robots and machines), thus making the employment of human labour more attractive. However, a robot tax would generally punish firms that aim to become more cost-efficient. It could deter capital investment and, in the worst case, any further innovation. Without some international framework, it could lead to intensified regulatory competition between nations, protectionism and the migration of capital towards more attractive jurisdictions. However, how realistic is such an international framework in times when (allied) nations try to maximise their own benefit first?

To compensate for (mass) unemployment, a robot tax could give governments the financial means to implement a basic income scheme granted to every citizen of a nation. A basic income of this nature could take various forms, ranging from an unconditional or universal basic income (UBI) to a negative income tax (NIT), as advocated, for example, by economist and Nobel Prize Laureate Milton Friedman in his book “Capitalism and Freedom” from 1962. The basic income could replace most current social spending items (such as public expenses on health insurance or housing allowances). For better or worse, the introduction of a basic income would mean a fundamental change to the architecture of our welfare states, as it would lead to a complete decoupling of income and employment. The ”notion of performance” – inherent in our market economies – would be replaced by the “notion of social solidarity”. Would that lead to reduced engagement by people with high professional and economic ambitions and thus hamper innovation? Would creative people move to countries where individual performance was still rewarded? Where are the political forces to promote such a dramatic shift?

Winner takes all – platform economics, regulation and international competition

As has been the case with most revolutionary technology or (global) economic trends, the changes triggered by digitalisation extend to policy fields and

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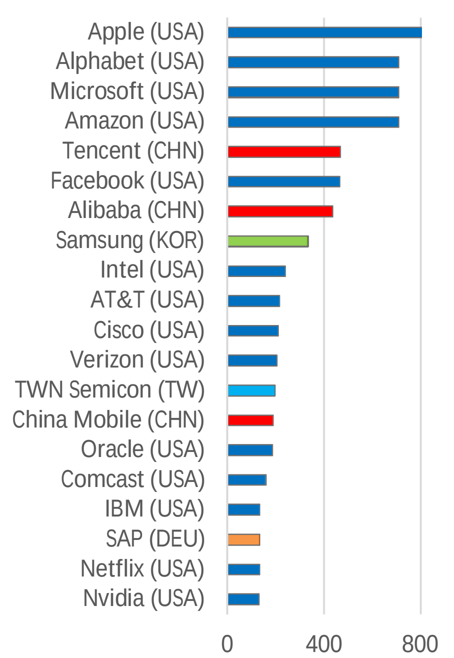
45 In this context, the OECD and G20 countries are intensively studying the tax challenges arising from digitalisation and working towards the necessary changes to the international tax system to combat base erosion and profit shifting (BEPS) by multinational companies. See also OECD (2018). Tax Challenges Arising from Digitalisation – Interim Report 2018. Meanwhile, the European Commission (EC) has pressed ahead with the implementation of new rules for the taxation of digital activities. See also EC (2018). Fair Taxation of the Digital Economy.

46 On a practical level, this raises the question of how to define a taxable robot/AI system.

Battle between US and Chinese tech superstars 28

Market capitalisation (USD bn), April 25 2018

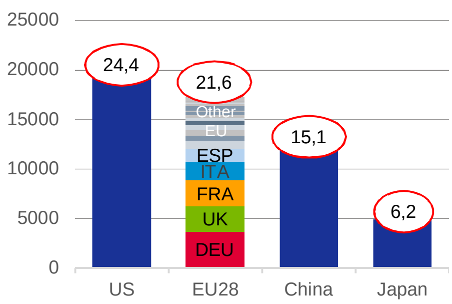


Note: we use a broader definition of "technology" companies than Thomson Reuters Datastream and include companies for which ICT solutions or digital/platform solutions are at the core of their business model.

Sources: Thomson Reuters Datastream, Deutsche Bank Research

Fragmented European economy 29

2017 GDP, nominal, USD bn (% share of world)



Sources: IMF, Deutsche Bank Research

economic governance. Governments might have to assume greater responsibility for navigating the effective transition into the digital world. As the pace of technological change and the related launch of new business models are unlikely to slow, the ability of the state and regulators to keep pace is challenged. Analogue regulation of a digital world is sort of unchartered territory. At the same time, regulation plays an important role in fostering or hampering the adaptability and the competitiveness of a digitalised economy.

The challenge is all the more obvious given that the digital (r)evolution is not constrained to national borders and, more often than not, requires global action. Politicians and regulators will have to cope with increasingly convergent markets or the confluence of platforms and seek a balance between eliminating barriers to reap the full benefit of a digital economy and the indispensable rights of consumers and data owners. The latter in particular is likely to be shaped by different end-user preferences and, in turn, by different national approaches, which might hamper the creation of a level playing field for all players in the (global) market.

On a regional level, the EU is addressing these issues through the creation of the digital single market. It is also taking aim at the tax practices of digital platforms[47].The business model of many of these companies relies on cross-border sales of products and services, which raises the question of whether governments can and should tax such value where the consumer resides, even if the company has its physical domicile elsewhere. International initiatives by the OECD and the G20 already address tax base erosion and profit shifting and might play an even larger role regarding taxation in a borderless digital world[48].

To forge ahead with the digital transformation and maximise the benefits for economies and societies, a balance needs to be found globally between successfully promoting the digital industry and the related knowledge creation and diffusion, and avoiding the risk of rising protectionism. Competition in breeding national champions, the role of governments in targeted investment, control of and protection against foreign investment and takeovers might weaken the principles of open markets and free trade.

Such differences are also at the root of the trade tensions between the US and China, which extend to the EU as well. The US and Europe also started to become more wary towards foreign investment, notably in the tech sector. Will “knowledge wars” become the new trade wars and the technology race lead to “protectionism 2.0”[49]? How will AI affect global trade patterns and global value chains? The discussion of possible responses by trade (and security) policies and of the role of global institutions such as the WTO has only just begun.

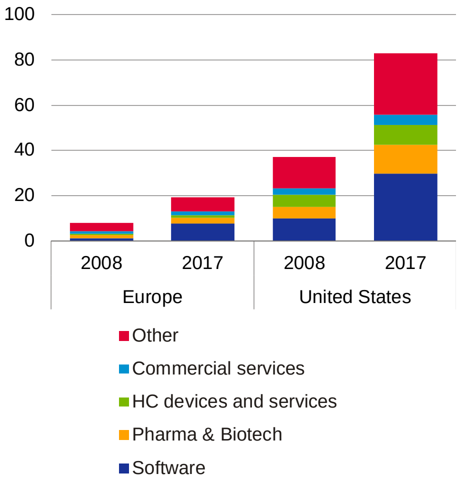
EU digital strategy – between a rock and a hard place

There are significant differences between the world’s three largest economies – namely the US, the EU and China – when it comes to designing economic policies (e.g. intellectual property rights) and the degree of openness of their domestic markets. So far, the US has followed a strongly market-based approach and has been very sceptical of regulatory efforts, for example in Europe. The digital industry in the US has benefitted from a large domestic market, its innovative and risk-friendly culture and the unique infrastructure and concentration of companies, talent, world-class universities and venture capital in the West Coast’s sunny Silicon Valley. Growing at the heart of ICT

[47] See EC (2018). Fair Taxation of the Digital Economy, and EC (2018). Shaping the Digital Single Market.
[48] See OECD (2018). Tax Challenges Arising from Digitalisation.
[49] See Eurasia Group (2018). Top Risks 2018.

Venture capital deal flows US and Europe 30

USD bn

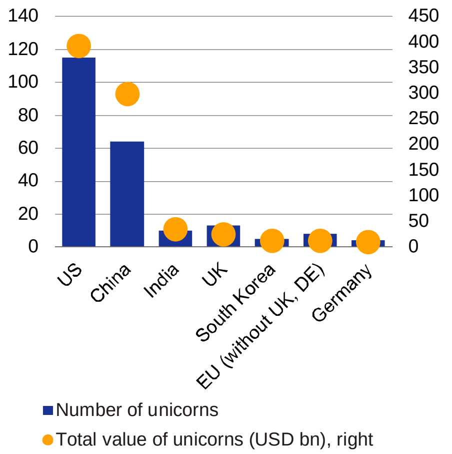


Note: Europe includes Israel

Sources: PitchBook, Deutsche Bank Research

US leads with unicorns, China catching up 31

Startups with a valuation of USD 1bn or more*



*accessed in April 2018

Sources: CB Insights, Deutsche Bank Research

developments over the last several decades, US companies certainly benefitted from a strong first-mover advantage, rapidly spreading their business across borders (supported by the fact that English is a global language). While US tech giants gained (dominant) market share in key segments of the digital economy around the world, China's "Great Firewall" stopped their advance to some extent and helped foster China's own major tech companies, which now rank among the world's most highly valued market-listed companies. Framed by China's strategic aim for leadership in AI and robotics and its goal to spur growth and innovation, its tech superstars are increasingly competing with their US peers for global market share and talent from abroad, while Chinese companies invest in strategic industries around the globe[50].

Europe lacks the likes of US/Chinese tech giants. Its domestic market is the second largest after the US, coming in ahead of China, but it is fragmented in comparison, not least due to cultural, language-related and regulatory differences. The EU is prosperous, technologically advanced and has a well educated workforce, but when it comes to the availability of venture capital and an entrepreneurial (risk) culture, there is still a vast gap with respect to the US. In addition, the EU's regulatory framework and free-market policies do not allow for a Chinese-style government approach to sheltering and nurturing its tech industry. At the same time, Europe seems to be in the lead when it comes to setting standards for regulation and privacy protection in the digital age[51]. The EU's new data privacy law, known as the European General Data Protection Regulation (GDPR), goes into effect on 25 May 2018 after a two-year transition period. This framework aims to harmonise privacy laws within the EU in order to protect citizens' personal data, ensure a free flow of data across the Union and reduce regulatory impediments to competition[52].

While critics fear that tight regulation might cause the European digital economy to fall further behind compared to international peers, supporters of the GDPR regard high data-protection standards as a potential competitive advantage for companies that base their business model on building trust and respecting privacy. As recent revelations about data sharing between Facebook and Cambridge Analytica have illustrated, data privacy and digital identity have become increasingly important issues, both on an individual and societal level. Today, identity theft, i.e. the fraudulent use of another person's personal details, is growing into a frequent phenomenon. In an increasingly digitalised future, identity theft and other cybercrimes may become essential risks to growth and economic stability, and securing the integrity of private data will be of the utmost importance. Blockchains, with their immutable, accurate and final data-storage capabilities, seem to be a promising approach worthy of closer examination[53]. To this end, blockchain solutions paired with further advances in AI and robotics have the potential to be the backbone of a digital future. Countries and jurisdictions that become forerunners in securing personal identities on blockchains (self-sovereign IDs) could gain a lasting competitive advantage, as many additional innovations may be established on top of a clear regulatory framework for digital identities.

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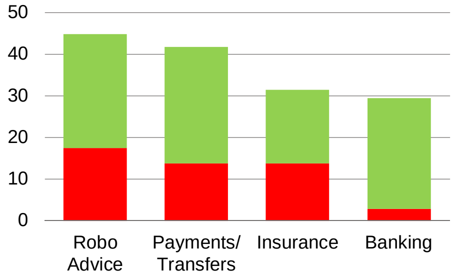
[50] See also The Verge (2017). China and the US are battling to become the world's first AI superpower.
[51] See also Gabriel, M. and M. Mahjoubi (2018). A European vision for human-centred digital platform ecosystems.
[52] See also EC (2018). 2018 reform of EU data protection rules.
[53] See also Harvard Business Review (2017). Blockchain Could Help Us Reclaim Control of Our Personal Data.

Use of FinTechs by service 32

% of survey responses* in 2016

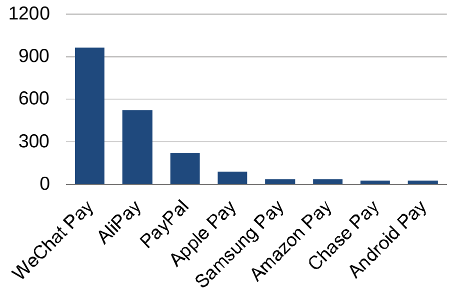


*"Please indicate if you use the following products and the nature of the firm you interact with for each product."

Sources: Capgemini, Deutsche Bank Research

Mobile payment platforms on the rise 33

Number of users in million in 2017*

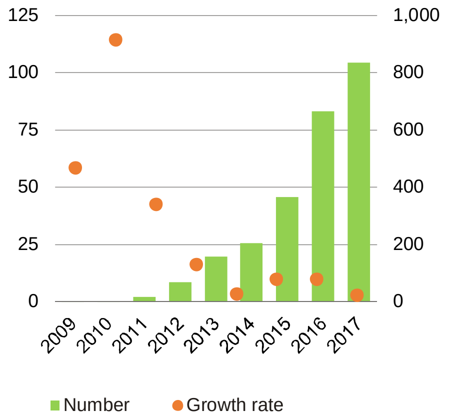


*for WeChat Pay and PayPal Q3, for all others Q1

Sources: Various sources, Deutsche Bank Research

Bitcoin payments: more and more ... 34

Number of transactions in millions (left); growth rate (yoy) in % (right)



Sources: blockchain.info, Deutsche Bank Research

Rise of the robo-bankers? Technology, banks and financial markets

Banks usually adopt new technologies early on. That said, drastic technology-driven changes in recent years have occurred very fast. The arrival of non-traditional players, such as start-up financial technology firms (FinTechs), which are active in several traditional banking services − from payments and money transfers to asset management and trading − represent a challenge for banks. What is more, very large technology firms (big tech) are entering financial intermediation. With so many different players competing against each other for market share and clients, the fundamental question is who the future front runners in this race will be. A sine qua non for survival is the use of new technologies, such as artificial intelligence (AI) and distributed ledger technologies (DLT), which require a closer look[54].

AI is seeing rapid adoption in banking and trading[55]. Potential fields of application are 1) customer-focused uses, such as customised products or client-facing chatbots; 2) operations-focused uses, such as risk management or fraud detection; 3) trading and portfolio management, such as robo-advice. AI and machine learning thereby enhance the efficiency of financial institutions and offer opportunities for reducing costs and boosting profitability.

However, AI is not without risk. AI and machine learning could create 'black boxes' in financial markets, which may turn out to be detrimental, especially during tail events. This risk is due to excessive market concentration, directional trading and interconnectedness. Even more importantly, cyberattacks that disrupt critical securities-trading infrastructures may lead to system-wide financial stability risks due to knock-on effects via fully automated fund management and trading.

Distributed ledger technology calls into question the traditional organisation of financial markets as centralised, tiered networks, as DLT enables financial peer-to-peer transactions without intermediaries ("cut out the middleman"). Technological progress in DLT will be key, especially in terms of scalability, safety and ease of use. Governance, legal aspects and regulation will also determine the attractiveness of decentralised networks, as well as client expectations. Who will code and who will govern the rules of a decentralised network?

As a pioneer in peer-to-peer electronic cash networks, Bitcoin impressively demonstrates the viability of DLT, blockchains and open-source systems governed by consensus. However, the price of such a system is complexity and inefficiency, at least compared to traditional centralised systems. Ironically, classic "middlemen", i.e. trusted third parties, are exploring blockchain technology as a way to provide or improve their services. Central banks are analysing DLT as a means for providing digital cash, while investment banks are developing DLT-based solutions for securities trading and settlement. In the end, clients may simply have a wider choice, i.e. between products brokered by financial service providers, "true" peer-to-peer products or anything in between. Cryptocurrencies may prove potentially disruptive to the traditional financial sector. If their low scalability should become a thing of the past, they could become real competitors of fiat money[56] and breathe new life into the debate over competing currencies as famously promoted by liberal economist Friedrich

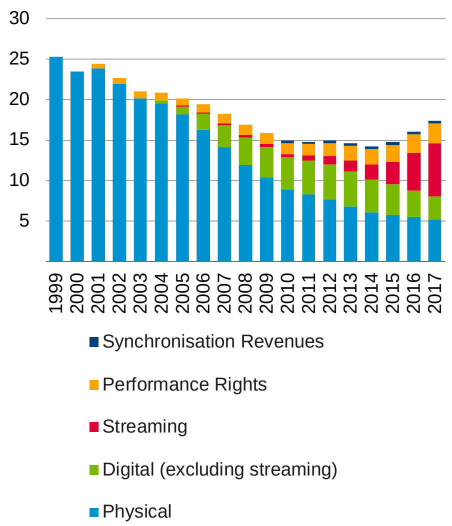
[54] See also McAfee, A. and E. Brynjolfsson (2017). Machine, Platform, Crowd: Harnessing Our Digital Future.
[55] See also Boobier, T (2018). Advanced Analytics and AI: Impact, Implementation, and the Future of Work.
[56] See also Lagarde, C. (2017). Central Banking and Fintech – A Brave New World?

DLT/Blockchains 35

(1) Distributed ledger technology (DLT)	Decentralized information recording as hundreds or thousands of servers are distributed around the world.
(2) Block-chain	Transaction chain being immutable as a change of the transactions in the past change the present transactions and invalidates transactions and the whole blockchain.
(3) Open source	Freely available software and code as well as open source community supporting the design, development, coding and governing of public blockchains.
(4) Consensus	DLT, open source and consensus mindset of Bitcoin community provides the bases for decentralized governance structure.
(5) Boots-trapping	Module (1-4) are no new innovations. However, the assembling of modules and the bootstrapping of Bitcoin remains a big innovative leap forward.

Source: Deutsche Bank Research

Global recorded music industry revenues, USD bn 36



Sources: IFPI, Deutsche Bank Research

Hayek[57]. Any new large-scale bailout and resumption of quantitative easing might bolster the adoption of cryptocurrencies, especially if they have noticeable inflationary consequences. No matter how the organisation of financial interaction ultimately develops, competition between centralised and peer-to-peer networks fuels innovation. Clients will likely benefit from a wider choice of services and increased competition over prices.

Disruptive technologies and creative destruction from a sector perspective

Digital technology has become so commonplace in some areas of everyday life that users do not even remember the status quo ante any more. Take, for example, the music industry. Many young people have never bought a tape or a CD – they only use streaming or download services. This sector also illustrates the problems (at least from the suppliers' side) related to digitalisation: illegal downloads or video streaming services eat away at creators' income or even reduce it to zero.

In fact, the media sector as a whole is a good example of how digitalisation may turn a sector upside down. Print media outlets are losing market share to online portals, and advertising activities and advertising income are shifting accordingly. Traditional TV stations have to compete with streaming services, which provide their content on demand. Online chats supplement or replace phone calls (and, in some cases, personal meetings). Overall media consumption has increased and is spread across more devices, which may sometimes be used in parallel (e.g. smartphones and TV). Thanks to flat rates for specific services, users are no longer concerned about spending. And most of them are quite content to exchange personal data for "free" services. Many consumers adapt very quickly; some of the aforementioned services were developed only a few months or years ago, but some consumers cannot do without them anymore.

Digital products, digital marketing, digital procurement – the remainder of the value chain is following suit

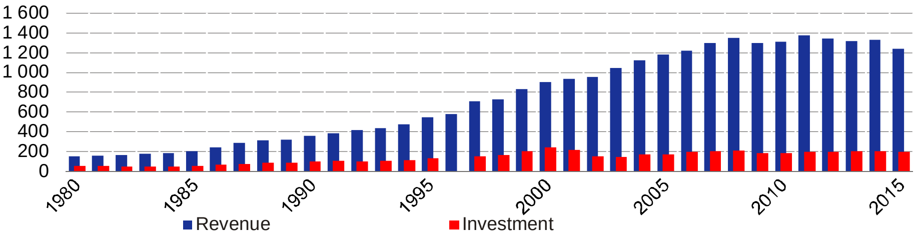
From a sector vantage point, there is a general pattern to the trend towards a digital economy. First, digital versions of certain products (such as music or print media) were created, which can be marketed via digital channels and reproduced at extremely low additional expense. In some cases, they can even be copied illegally or not for monetary compensation. In the second stage, many consumers and companies switched to procuring or ordering physical goods via the internet, and the practice continues to gain ground (e-commerce). The share of e-commerce in total German retail sales probably amounts to approximately 10% by now (the latest available official figures are for 2015: 8.5%). The internet has made it easier to compare prices and products, has reduced information asymmetries and intensified competition.

In the last few years, digital technologies have started to spread towards other sectors and parts of the value chain. Creating network connections between staff, machines and materials can help make industrial production more efficient. Industrial products are changing, and so is their use (take, for example, the "sharing economy"). Modern logistics services cannot do without digital technologies any more. Even sectors where physical activity plays a major role (e.g. construction and crafts) and personal services (e.g. healthcare and public

57 Hayek, F. (1976). Denationalisation of Money.

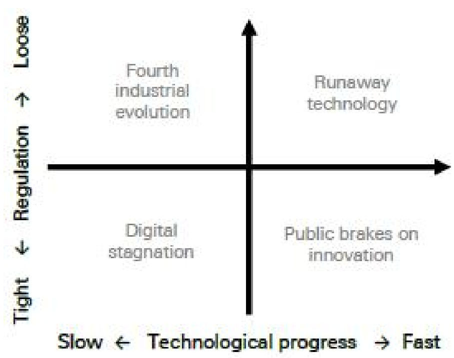
administration) are increasingly relying on digital technology. In the transport sector, digitalisation enables efficient mobility, and autonomous driving is no longer science fiction. In the energy sector, digital technologies will help align energy production and consumption. Ultimately, digital technologies will change market and competitive structures across all sectors, and the lines between sectors may become blurred. The pace and extent of these changes will depend on a number of factors, not least on consumers' adaptation behaviour. While the changes will not always be as earth shaking as they have been in the music industry, evolutionary developments may also present a major challenge to the affected companies.

Trends in telecommunication revenue and investment 37



Source: OECD

Digital future - scenarios 38



Source: Deutsche Bank Research

3. Into the unknown – technology, policymakers and the future

Numerous debates about the importance of digital technologies for economic and social developments remain quite abstract today, particularly at the political level, where "digitalisation" has become a buzzword that pops up in almost every official speech. To some extent, the lack of concrete proposals and concepts is due to the fact that the individual players define digitalisation in very different ways. And their definitions do not necessarily run counter to each other.

For this reason, it is quite difficult to discuss the short-term consequences of the current technological transformation without getting lost in a maze of complex details. A look at the medium- to long-term future is even more overwhelming. Due to the numerous uncertainties regarding the technology-socioeconomic feedback loop, it appears almost impossible to make concrete forecasts about "digital society" in 15, 20 or 25 years. Most likely, when we reach that time, the "digi"-prefix itself will sound anachronistic and be replaced by a whole series of new buzzwords related to the latest technological breakthroughs. Without the gift of foresight, it might still help to develop scenarios in order to define a framework within which we may assess the future impact of digital technologies on the social and economic environment and reduce the complexity somewhat.

Technological progress and government regulation will play a key role

It would go beyond the scope of this report to describe individual scenarios in detail. We will therefore only attempt to sketch out the dimensions that form the framework for the different scenarios. We believe that two factors in particular will shape digital society – at the same time, it is very uncertain how they will develop. The first is the pace of technological progress in the area of digital technologies and applications. Tech companies and research institutes will have a determining influence on this factor, but also national and supranational investment programs and government-industry partnerships will influence speed and spread of technological development over the upcoming years. As technological progress is often erratic and its diffusion is unclear, it may be regarded as the disrupting factor. The second important factor is the degree of (state) regulation of new technologies and applications, as regulations provide the structures for the new developments. This can be considered the constraining or guiding factor. Regulation (in democratic societies) may also be considered as the manifestation of societal consensus on what technological future we should collectively aim for.

Future scenarios could be seen as an interplay between technological progress and regulation. Both factors may take one of two different directions. Technological progress may be fast and ground-breaking or (unexpectedly) slow and hardly innovative. State regulation may be loose and (financially) supportive as well as lagging behind innovation or tight and restrictive.

Taking into account these four factor combinations, we arrive at four quadrants within which we can develop different scenarios. Since it is impossible to quantify the actual potential developments, we can only describe their qualities. It is important to remember that each scenario describes only one of many potential futures and that it is explicitly not meant to serve as a forecast. Of course, other (related) factors will influence digital society in future, for example market and competitive structures or the pace at which users take up new technologies. The individual factors can be determined in greater detail in order to examine the impact of digitalisation on specific economic or social areas (e.g. sectors or policy areas). Moreover, the scenarios offer sufficient leeway to take into account regional differences.

Our future publications on digitalisation will come back to these aspects. We will use the framework sketched out here to broach more specific questions and topics and flesh out these basic scenarios in greater detail.

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