Industry 4.0 creating a buzz in western hemisphere: But watch out for China pulling into the fast lane

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Abstract

Industry 4.0 is currently the subject of intense debate. Large companies, small and medium-sized enterprises and members of the public all over the globe are interested in the concept that, when successfully implemented, sets out to revolutionise the way goods and services are created and distributed. Here, empirical experience shows that companies with a less established process structure are more likely to embrace the new elements of industry 4.0. Indeed, this could also hold true at the industry level in general. Modern industrial structures that were built up comparatively recently are well fitted for the upcoming digital evolution. This would have severe implications for countries' competitive advantage on international markets. China sets out to play a leading role in this digital evolution by a comprehensive upgrade of the entire economic structure in China. The country is determined to seize the outstanding opportunity at hand.

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Summary

Industry 4.0 is a subject with global implications. Essentially, the concept comes down to the reorganisation and automation of value chains. If successfully implemented, industry 4.0 sets out to revolutionise the way goods and services are created and distributed, reshaping the industrial landscape on a national and global scale.

Thus, China is determined to seize the opportunities of the digital evolution. Chinas government actively promotes the transformation towards an innovation-led growth model through large policy programs. The scope of funding for seven Strategic Emerging Industries is placed in the Five-Year-Plan. Thus, the government unveiled its "Made in China 2025" program.

Here, China is considered the most mature adopter of industry 4.0 worldwide. Aside from world leaders such as Huawei and ZTE, myriads of Chinese small and medium enterprises create an updated version of German Mittelstand for Far East.

Notwithstanding, the rank and file of China's companies did still not embrace the benefits of previous industrial stages. The country is and will remain highly heterogeneous. Therefore, industry 4.0 is realised locally and in an evolutionary fashion. Overall, China's implementation of industry 4.0 is still in its infancy. Nevertheless, by managing to extrapolate the momentum, China is pulling into the fast lane.

Industry 4.0 creating a buzz in western hemisphere:

But watch out for China pulling into the fast lane

1. Industry 4.0: Hype or hope

All around the globe, Industry 4.0 (also known as integrated industry) is on everyone's lips. In Germany big companies, the Mittelstand, and certain members of the public are examining the new opportunities associated with it (see Schneider). This interest has undoubtedly been boosted not only by the focus that industry 4.0 received by Hanover Fair, the major international industry fair, but also by the government's support worldwide, which besides raising its profile at different summits includes also remarkable grants and public initiatives(see De Propris and Bailey).[1] However, in the vast expanse encompassing augmented reality (see Gushima and Nakajima, Heng 2019 or Rauschnabel and Ro), Big Data, cloud computing, cyber-physical systems, RFID chips, Internet of things and services (see Ezell, et al., pp. 17), machine-to-machine communication, Second Machine Age (see Brynjolfsson), and Smart X (i.e. intelligent features in any things, e.g. products, grids, factories, mobility, etc.) (see Yudono, et al., pp. 330) the term industry 4.0 remains imprecise – which is possibly the intention of many marketing strategists. This imprecise definition of industry 4.0 repeatedly gives rise to overblown expectations, which lead to disappointment. Providers advertise industry 4.0 offerings as

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[1] Public initiatives like "KI Made in Germany", a program arranged by German government in 2018. There, the government will spend EUR 3 bn. for AI projects in Germany until 2025.
For comparison: In Tianjin, a harbour city in north-east China, alone, they launch a funds ad valorem of EUR 15 bn for AI projects. Thus, five times as much as in entire Germany.

completing automation and thus enabling cost-effective adaptation of production to individual requirements, as well (see Heng 2017).

The PR campaigns in many countries around the globe surrounding industry 4.0 has ensured that companies and institutions all around the globe cannot get around being aware of the concept for a while (see Staufen or Papula). However, with expectations raised by this campaign what happens all too often is that the fundamental idea of boosting efficiency via sensible automation gets lost in the hype surrounding the buzzword.

Empirical experience shows that companies with a less established process structure ("greenfield investments") are more likely to embrace the new elements of industry 4.0. Modern industrial structures that were built up comparatively recently are well fitted for the ongoing digital evolution. If true, this would have severe implications for countries' competitive advantage on international markets. China sets out to play a leading role in this digital evolution by a comprehensive upgrade of the entire Chinese value chain. The country is determined to seize the outstanding opportunity at hand, as the "Made in China 2025" program underlines flanked by intensive legislative support for innovative enterprises. The affaire about Meng Wanzhou, CFO of Huawei who was jailed in Canada in 2018. This gives an impression of the very close relationship between economy and administration.

This study analyses the economic potential of industry 4.0. The first section examines the principles of industry 4.0, identifying the most important terms and concepts as well as the key drivers and obstacles. The second section presents business ideas in the industry 4.0 environment. The third section describes the differences between Germany and China's way towards industry 4.0. In this regard, the section presents policy actions initiated by the Chinese government. In particular, we look at private-public cooperation to enable and facilitate company level action, ICT infrastructure, workforce quality, and a sound legal framework of data security and data protection (see Ahrens and Spöttl, Albrecht or Odenbach, Göll and Behrendt,). The final section presents a conclusion and a forecast.

2. Principles of industry 4.0

2.1. Next stages of development ahead

The stages of industrial development have different names depending on the geographical location and the area under examination (e.g. environment, technology) (see Bauernhansl, or Brynjolfsson and McAfee). In this analysis we seek to follow the logic of industrial development, which was developed especially in Germany in close cooperation with the academy of technical sciences, acatech (the National Academy of Science and Engineering), and the Forschungsunion Wirtschaft – Wissenschaft (see acatech).

According to this, the first industrial revolution commenced at the end of the 18th century with the introduction of mechanical production equipment, such as the mechanical loom for goods manufacturing. With the advent of electrically powered machinery used for mass production based on the division of labour came the second industrial revolution at the turn of the 20th century. The third industrial revolution then commenced in the 1970s. It was based on the use of electronics and information technologies to automate production processes. This entailed machinery performing not only a large proportion of previously manual tasks but also a number of the intellectual tasks.

The fourth industrial revolution, or industry 4.0 for short, is to become a reality in the coming decade (see Gornig/ Schiersch). The political debate about the term industry 4.0 focuses equally on the important and abstract objectives. For its promoters, industry 4.0 is not only about improving Germany's international competitiveness, it is also seen as a tool for tackling the most pressing global challenges (for example, the consumption of renewable and non-renewable resources) as well as specific national challenges (for example, the labour supply that is changing due to demographic shifts).

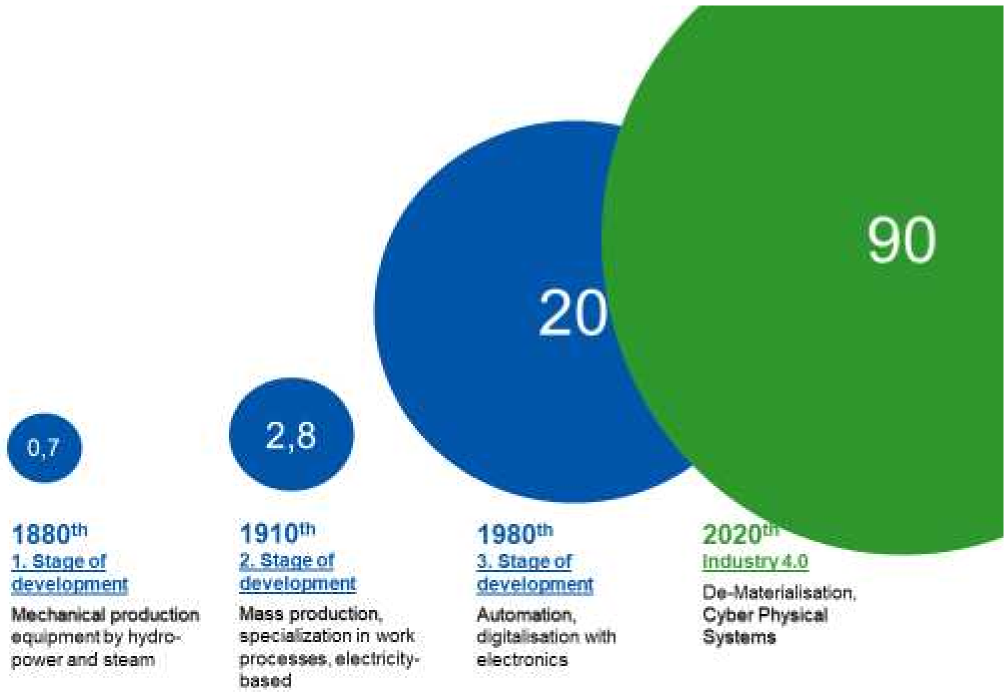

Fig. 1: Development of economic output concerning economic revolutions
GDP worldwide, USD tr (purchasing power parity adjusted)
(Source: Author's illustration, according to ZVEI, 2013) ***Insert "Fig1_TechRevol_DFKI.pptx"***

2.2. Source of remarkable fascination

Industry 4.0 is focused on smart products, procedures and processes (smart production). A key element of industry 4.0 is therefore the smart factory. The smart factory controls the fast-growing complexity while also boosting production efficiency. In the smart factory, there is direct communication between man, machine and resources (see Mertens). Smart products know their manufacturing process and future application. With this knowledge, they actively support the production process and the documentation ("when was I made, which parameters am I to be given, where I am supposed to be delivered.").

With its interfaces to smart mobility, smart logistics and smart grids the smart factory is an important element of future smart infrastructures. Conventional value chains will thereby be refined and very new business models will become established. Thus, Bitkom (the association for the German ICT industry) and Fraunhofer IOA (public research institute that focuses on investigation of current topics in the field of technology management) predict that the industry could boost their productivity by 30% with the aid of industry 4.0 (see Bauer et al.).

However, essentially, the benefits of industry 4.0 are not limited to manufacturing. Logistics, financial services and healthcare are further sectors that will experience rapid change and substantial economic impact (see Ahrens and Spöttl). Often overlooked, agriculture will also be a major beneficiary of the vertical and horizontal integration in the value chain. Moreover, the internet of things and services can be used to improve crop irrigation, environmental monitoring, market circulation of agricultural products and traceability. By doing so, industry 4.0 will probably have a considerable impact on the economic livelihoods of millions of producers and certainly on billions of customers.

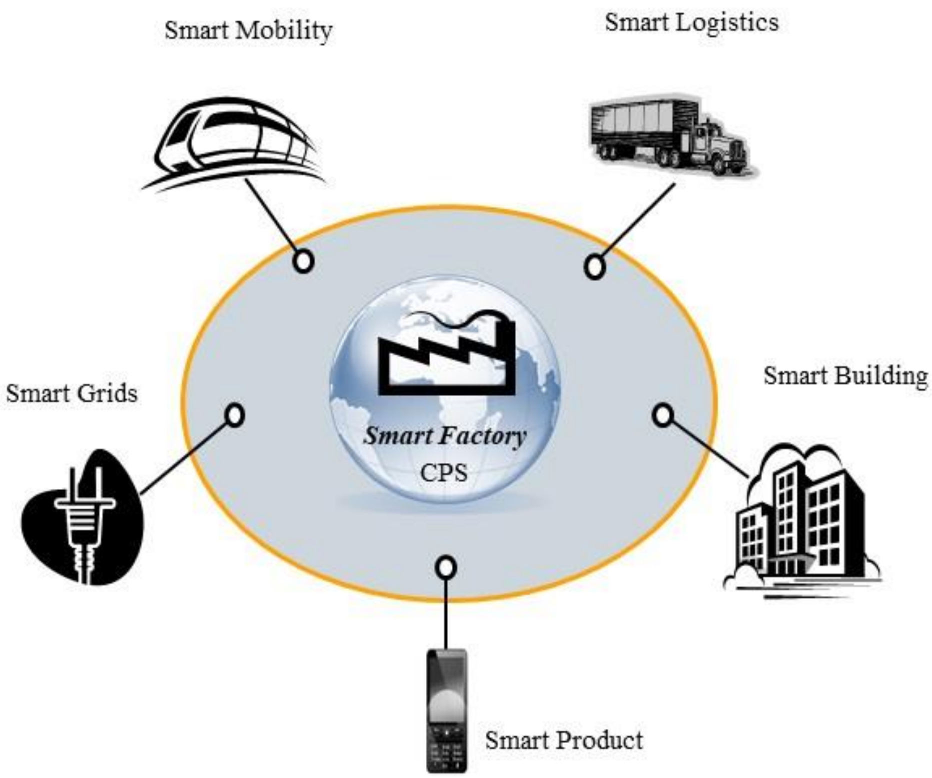

Fig. 2: In the centre of industry 4.0

(Source: Author's illustration, according to acatech, 2013) ***Insert "Fig2_SmartX_acatec.pptx"***

2.3. Economic boundaries becoming blurred

Basically, industry 4.0 describes the fourth stage of industrial development, with increasingly smart systems being formed in ever more closely integrated value chains. The industry 4.0-compliant production facility is thus a completely integrated smart environment (see Heininger). Accordingly, the implementation of industry 4.0 seeks to leverage existing technological and market potential, to tap it in a systematic innovation process and to bring this overall concept together with expertise, services and the knowledge of employees to create an optimised whole. Companies embarking on the road to industry 4.0 will pay particular attention to the following aspects:

— Vertical integration of the necessary process stages along the value chain;

— Horizontal integration at one stage of the value chain;

— Seamless end-to-end digital information flow across the entire value chain.

The industry 4.0 concept must therefore encompass not only value creation per se, but also work organisation, business models and downstream services. It does this by using information technology to link up production, marketing and logistics and thereby captures all resources, production facilities and warehousing systems. The re-organisation thus extends from the energy supply and smart power grids through to advanced mobility concepts (smart mobility, smart logistics). On the technical side, the concept is based on integrating cyber-physical systems into production and logistics and the rigorous end-to-end implementation of the internet of things and services in industrial processes. In this smart environment, the concept of the internet of things and services that was devised already a decade ago will actually now become a reality.

2.4. Cost-cutting possibilities

The user firms want industry 4.0 to help them implement cost-efficient manufacturing. What is new here is that the optimisation is performed constantly during ongoing operation and across the entire value chain. The main areas where such potential lies are as follows:

— Capital costs: Companies that optimise their value chains and increase their manufacturing automation thereby reduce their tied-up capital.

— Energy costs: Companies can cut their energy costs via efficient use and smart control of their plant facilities. Many companies pay little attention to this cost item, but it is usually quite a significant sum (s Odenbach et al.).

— Personnel costs: Companies with highly automated production processes tend to require a declining number of low-skilled employees.

Making a sound assessment of the overall effect (including the costs of training, implementation and maintenance) within the company will prove difficult in most cases, though. This is particularly the case because numerous user companies, especially SMEs, can often only very vaguely estimate their actual costs (and thus also the necessity to undertake restructuring).

2.5. More than narrow-minded cost-cutting focus

Industry 4.0 is, however, by no means limited to the area of costs. Rather, the concept is broad in scope and is described by experts as extremely relevant. For instance, in what is undoubtedly an optimistic projection, acatech asserts that firms could boost their productivity by 30% with the aid of industry 4.0.

The main parameters that open up the potential for this increase are flexibility, lead times, batch size, and new services and work structuring. We shall address these parameters below:

— More flexibility: Networking enables business processes to be structured more dynamically. Production procedures in particular are to react more flexibly to changes in demand or breakdowns in the value chain that occur at short notice. At industry 4.0 companies individual production lines organise themselves independently according to demand. If one machine on this line breaks down, production is reorganised autonomously via an alternative channel.

— Reduce lead times: Seamless data collection enables the rapid use of production-relevant data for near-term decision-making regardless of the location. This means industry 4.0 users can reduce market lead times for innovations. Industry 4.0 in particular presents start-up firms with especially attractive options.

— Adapting to customer requirements with small batch sizes: Industry 4.0 allows the incorporation of individual customer-specific criteria concerning design, configuration, ordering, planning, production and operation as well as enabling modifications to be made at short notice. Industry 4.0 is intended to ultimately even enable rapid and inexpensive low-volume production runs right down to one-offs (a batch size of 1); for example, in the automotive or furniture manufacturing sectors (see Corò et al.). Smart production organisation and new technologies such as 3D-printing processes are going to be used.

— New offerings of downstream services: In the business-to-business segment, industry 4.0 opens up potential for high-performance services for the near-term evaluation of big data.

— Attractive work structuring: Modern organisational structures enable production that is more flexible. This chronological and spatial flexibility is likely to be attractive to many workers. This in turn is also a positive argument in a labour market that is changing due to demographic developments and given the shortage of skilled workers that is set to become increasingly acute. After all, a company with advanced, flexible work models should have the best prospects in the contest for increasingly scarce "top talents"; this applies even more if it also becomes involved in the design of the required further education and training measures (see Schlund, et al.).

2.6. Challenges at technical, economic, legal, organizational part

While there are highly promising benefits associated with industry 4.0 it does also present several technical, legal, economic and organisational challenges for companies in the value chain (see Chromjaková). The most important of these challenges lie in using the collected data in real time, the utilisation of production capacities, the complexity of production organisation, integration in the value chain as well as the issues of data protection and data security (see Prause and Günther).

— The real-time evaluation and utilisation of the high volumes of data created in the value chain: The be-all and end-all of the industry 4.0 concept is that data collected along the value chain is evaluated for its relevance in real time and utilised for organising production. This necessity represents one major specification for IT systems (see Soder).

— Optimum capacity utilisation in autonomously organised production: Production in an industry 4.0 company can deal flexibly, efficiently and quickly with fluctuations in production and malfunctions in individual production areas using the available capacities. This optimisation procedure is extremely complex and will come into conflict with discretionary ad-hoc interventions.

— Integration in the value chain: The industry 4.0 idea is based on rapid and efficient data transmission within the value chain. This objective is predicated on infrastructures and processes being coordinated as well as interfaces and protocols being clearly defined. As long as there is no general standard for these technical prerequisites, i.e. that each proprietary system is incompatible with the other, it is extremely costly for a company to switch into a different value chain; and in some cases it is actually economically impossible (see Baum).

— Data protection and data security are crucial issues: Opinions are divided about comprehensive data exchange along the value chain. After all, the advantage of production flexibility is offset by the disadvantage of possibly to close a link between supplier and customer and a disclosure of company processes (i.e. extremely sensitive internal strategic data). The risks pertaining to data protection and data security are serious: the opportunity to be able to adjust applications does make industry 4.0 appealing to users. However, the extensive exchange of data that accompanies industry

4.0 also makes users an attractive target for hackers, though. In such attacks, the intention may not only be the theft of relevant data, but also sabotaging the entire production process, so these may be risks with a macroeconomic dimension.

A foretaste of the risk is the case of the Lukas hospital in Neuss/ Germany. After an attack by a Trojan in 2016, the hospital was totally paralysed for several days – including the emergency units – and run up a bill of more than EUR 500,000. The research department of Deutsche Bundestag expects the collapse of civilian life in a worst-case scenario for massive hacker attacks (see Deutsche Bundestag).

Accordingly, when the contract is being drafted the diverse facets of data protection and data security are extremely important to industry 4.0 users. For example, it needs to be examined whether the exchange of critical data outside the EU already contravenes the legal provisions that apply to the company. This applies in particular because other jurisdictions have completely different rules regarding data protection and data security, especially also regarding the scope for government access to the data.

2.7. Expectations sometimes disappointed

Some of the hopes generated by the initial euphoria for industry 4.0 remain unfulfilled in practice. There is a great deal of uncertainty in this new field – and it is therefore imperative to query more closely the processes and steps required.

This means it is certainly possible that the total savings in a full cost calculation would actually be negligible for numerous firms. There is even the danger that the economic efficiency may decline overall, at least in the short term. Since those companies that choose industry 4.0 initially have to make significant investments (e.g. for consulting, software, hardware, training and fundamental reorganisation), it will be difficult to make a sound empirical estimate of the overall effect on costs and this will undoubtedly also take many years to be achieved.

3. Various business ideas

3.1. Market still in its infancy

The development of the industry 4.0 market is still largely a vision of an evolutionary process that will not become truly tangible until the second half of the coming decade. This long-term process also intrinsically contains great uncertainties. These uncertainties are also expressed in the surveys and assessments presented by experts.

The current situation is typical of a new trend such as industry 4.0. The idea is thus gaining ground much more slowly than had been widely hoped. This is also due to the opposition and structural obstacles that exist both on the part of users and on the part of providers of industry 4.0 offerings (see Chromjaková). This applies especially to the following four aspects:

- Opposition from the providers themselves: The comprehensive concept associated with industry 4.0 forces providers in particular to re-examine their traditional business models. In numerous areas, the hitherto usual on-site provision of services, software and hardware will be replaced. With these new offerings the sales channels, value chains and thus the margins will change markedly, as well. This is likely to encounter opposition within the organisations – at least in the early phase of the reorientation.
- Opposition from within the departments of the outsourcing companies: Before implementation of the restructuring measures the user firms have to persuade the individual departments to cooperate in the execution of these changes. The objective of this persuasion is to ensure that unfounded fears do not prevent the introduction of new technologies and processes that are advisable for the company as a whole. These fears are

likely to be wide-ranging – from losing one's job to having one's responsibilities curtailed (see Fergen). Openly addressing all the concerns is thus likely to be a task that the management should not underestimate.

— The lack of generally applicable standards: A recognised technical standard could accelerate the universal interoperable use of fully automated offerings from the wide-ranging industry 4.0 portfolio and overall market penetration; this is particularly true as numerous potential users are currently still holding back because of their uncertainty. These interested parties are particularly fearful of investing considerable resources in an offering, which might not correspond with the standard that eventually becomes established. Reaching agreement on a generally applicable standard is, however, likely to prove difficult for a variety of reasons. On the one hand, there are certainly also discernible cultural differences between the companies in the mechanical engineering, electrical engineering, electronics and IT sectors with regard to the multidisciplinary topic, especially also with regard to the path to standardisation. Standardisation in the fields of electrical engineering, electronics and mechanical engineering, for example, has traditionally been more reliant on repeated time-consuming consultations and committee work than on IT. On the other hand, many providers could also make the strategic decision to rely on proprietary offerings. Adopting such an approach could be allied to the hope of using the restrictions on interoperability to make it much more difficult for customers to switch to a different provider.

— Enhancing network availability and speed: Communication networks must be able to handle the constantly rising volume of data and quality requirements. If the communications network has insufficient capacity (especially with regard to system availability and speed), then fully automated processes will be affected by interruptions to operating processes and high downtime costs will thus be incurred, as well. The prospects of success for the new automation offerings therefore depend directly on the reach and performance of the communication network. The issue of the commercial foundations for industry 4.0 therefore is linked to the central macroeconomic issue of the expansion of the communications network.

3.2. A wide range of entities …

Experience clearly shows that industry 4.0 offerings need to be tailored specifically to the company and cannot be supplied "off the shelf". So the idea of industry 4.0 can basically be conceived in very diverse contexts (see Ittermann and Niehaus). The varied benefits associated with this development are shown by projects and prototypes developed by research establishments such as Deutsches Forschungszentrum für Künstliche Intelligenz (research institute for artificial intelligence, DFKI), or Fraunhofer ISS/ EAS, Fraunhofer IOSB, and companies such as Agco (agricultural technology), BorgWarner (drive engineering), Brütsch-Rüegger (tool technology), Bosch Rexroth (drive engineering), Bruker (measurement engineering), Daimler (automotive), John Deere (agricultural technology), Festo (process technology), Harting (network technology), Homag (mechanical engineering), HP (IT), Introbest (systems engineering), Kaba (safety engineering), SAP (IT), Seca (measurement engineering), Sick (sensors), Siemens (electronocal engineering), Stahlwille (tool technology), Trebing + Himstedt (process technology), Trumpf (manufacturing engineering), Volkswagen (automotive) or Wittenstein (propulsion technology) in the western hemisphere; but also Hisense (electonical engineering), Huawei (telecomminucations), Lenovo (IT), Mindray (medical engineering), Shinva Medical (medical engineering), Spreadtrum (semiconductors), Xiaomi (smartphones), or ZTE (IT) in China.

Fig. 3: Wide range of players in industry 4.0 (selection)
(Source: Author's illustration) ***Insert "Fig3_I40InPractise_Own.pptx"***

3.3. … and a wide range for applications

The corresponding breadth of applications is indicated by the following examples:

— Remote maintenance reinvented: Currently the remote maintenance of highly specialised production machinery requires individual communications solutions. This is how the mechanical engineering specialist links up to the company network of the production facility. Configuring and managing this link-up is very costly. In the smart factory of the future the production system links up with the appropriate experts via a telepresence platform depending on the situation. The machines autonomously supply the relevant data for the diagnosis.

— Changing supplier during the production process is made possible: At present, the manufacturer has a very big problem if a supplier is suddenly unable to deliver. It has to be quickly clarified how long the inventory will last, which products are affected and which firm could be the replacement supplier. Resolving such issues quickly enough is very complex and requires high-quality infrastructure. Industry 4.0 will directly enable the overall impact on value added to be estimated, including inventory level and logistical processing. Costs, the action required and risks can thus be derived sufficiently quickly. The comprehensive linking-up of production systems enables alternative suppliers and their capacities to be analysed in real time. Enquiries can then be made to the alternative suppliers in a supplier cloud, for example.

— Plant engineering resources are to be used efficiently via practical shutdown capabilities: Many production facilities currently continue to operate even during extended manufacturing downtimes, such as non-working shifts and weekends, and thereby consume large amounts of energy. The plant remains in operation around the clock so that there is no need for a long start-up phase. During production-free periods energy is thus wasted senselessly, especially by robots, extraction devices, laser sources and cooling equipment. Industry 4.0 enables this efficiency-enhancement potential to be tapped more effectively – assuming that the concept is already incorporated into the planning phase. With energy efficiency in mind, production-free periods for the machines are quickly recognised in order to switch them into an energy-saving standby mode. Demand-managed motors are used especially for this on extractor systems. Siemens has calculated that for a typical facility where laser welding technology is used for body-making this instrument could cut energy consumption during rest periods by 90%, which would result in an overall energy saving of 12% (i.e. consumption would drop from 45,000 kWh to 40,000 kWh).

— End-to-end system engineering enables customised products to be made: Usually the value chain structure is highly path-dependent and also static in nature. The special requirements of individual customers have hitherto not been incorporated into the production planning process – even though this flexibility in the manufacturing process would in fact be possible in principle.

  Industry 4.0 enables end-to-end engineering to be implemented. Production is monolithically developed from start to finish and thus coordinated with product development. Consequently, customers will be able to combine individual functions and components in the production process inexpensively according to their own requirements. Automaking is currently based on a predetermined production line. The functional scope of the individual stations is statically defined. The workers' tasks are geared directly to the requirements of the respective stations and are usually quite monotonous. If retooling is necessary in order to introduce a new product version this is time consuming and thus also expensive. This means that individual customer preferences, such as the fitting of a component from a different product group from the same firm, cannot be considered. The factory of the future consists of a flexible production line grid. The vehicle to be manufactured then manoeuvres autonomously through the production stations as a smart product. The flexibility of the production process allows a wide range of variation that is not limited by any central guideline.

— Agriculture is always also an engineering matter: Agriculture operates with biological systems, such as soil, plants, animals and the weather, which at the abstract level are linked with similar risks to those we know from the industrial environment. In a similar way to industrial the agricultural sector also faces global competition. It is thus to be expected that the innovations from the fourth industrial revolution will also transform the agricultural sector. Going forward, making production more flexible and customising products will certainly become relevant in agriculture, too. Integrating customers into value chains (as entities demanding defined product features, such as food retailers who use their own quality standards to try to distinguish themselves from their competitors) is equally conceivable as a cyber-physical system as is the inexpensive creation of standard products. In pilot projects associated with precision farming, mechanical engineers and IT experts have joined forces with agricultural experts and are already testing sensor-based fertilising modelled on a cyber-physical system. This also still requires well-qualified personnel, i.e. especially farmers with agro-technical expertise.

4. China's way promising

4.1. Economical structures promote leapfrogging

China's business environment is one of the most dynamic in the world. The labour market, in particular, has undergone dramatic changes and will continue to do so over the country's course of economic development. On the one hand, rapid economic growth has increased the demand for labour. On the other, China's seemingly infinite supply of labour is set out to shrink at the end of the decade, with an ageing population increasing the country's dependency ratio (age-population ratio of those typically not in the labour force to those in the labour force). Wages respond to the change in demand and supply of labour, giving rise to a new upper-middle income consumer class. In consequence the country's comparative advantage as well as its domestic demand structure shifts towards more capital and technology-rich end-user commodities.

The Chinese government has responded early to the challenge. Economic development shifted from a labour-intensive approach in agriculture and manufacturing towards capital-deepening industrialisation from the mid-1990s onward. Besides this, not least due to the growth recession Chinas government facilitated improvements in cost innovation and the transfer of technology through inward foreign direct investments, in particular joint ventures (Han et al.). As a result, the economy's industrial structure as well as export basket composition changed dramatically. Today, China is often labelled "the workshop of the world". However, the process of economic transformation is unlikely to end there.

The next step on the transformation ladder does not only involve a shift into higher-value added manufacturing, but also moving from "Made in China" to "Designed in China". This will be key in ensuring international competitiveness in an ever changing global market. More specifically, it requires embracing the huge benefits associated with industry 4.0 by actively promoting its comprehensive implementation within the business environment.

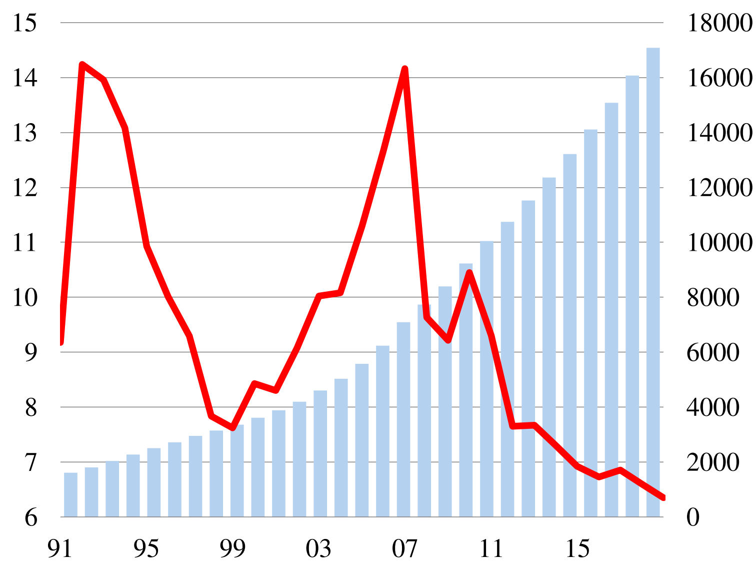

Fig. 4: Rapid economic growth in China

GDP per cap., USD in purch. power parities (right); % yoy (left), CN

(Source: NBS China, 2019) ***Insert "Fig4_GDPCI_WB.xlsx"***

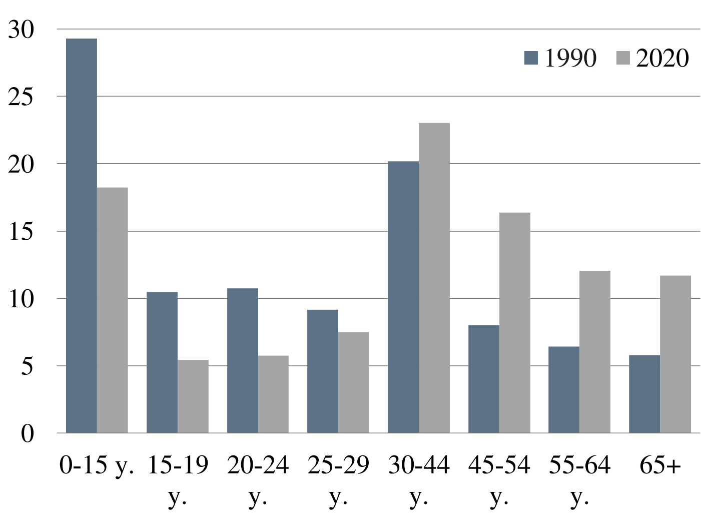

Fig. 5: China's aging population

% of population by cohort in CN

(Source: World Bank, 2018) ***Insert "Fig5_AgeStructureCI_UN.xlsx"***

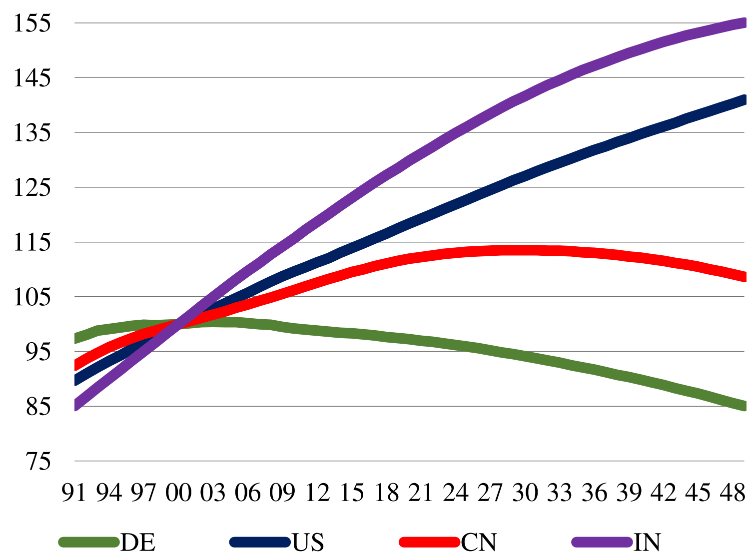

Fig. 6: Declining population in China and Germany ahead

Population by number, Index 2000 = 100

(Source: OECD, Statistisches Bundesamt, own calculation) ***Insert "Fig6_PopulationDiv_OECD.xlsx"***

4.2. Huge potential waiting to be harvested

The potential gains for China are immense, as they scale with the size of the industry. The country is the world's largest manufacturer. The output value of China's equipment manufacturing industry alone surpassed USD 3.2 tr in 2013, which accounts for around one third of the global output. China's Ministry of Industry and Information Technology estimates that the economy's automation industry is worth around USD 100 bn. According to the Industrial Federation of Robotics, the Asia-Pacific region is already the main market for robots. However, a successful implementation of industry 4.0 is not only a great opportunity for Chinese firms to get market shares. The boost in labour productivity becomes more and more a necessity to compensate for the loss in labour cost advantages and to ensure international competitiveness (see Das and N'Diaye).

What is needed to successfully implement industry 4.0? The good news is that, in principle, the technology to realise this vision is available to us today, in principle. It comprises production and performance reporting, condition-based monitoring, intelligent alerts and event management, calculation of key performance indicators and, ultimately, technology that promotes collaboration for improved decision-making. The necessary precondition for utilising this technology is a modern business environment defined by a variety of capabilities, such as e.g. high technological capacity of the workforce and a well-established ICT infrastructure (see Mertens).

For them to be in place, awareness is the starting point. The Chinese government has explicitly emphasized the importance of automation in the context of the internet of things and services for China's transition. Moreover, politics started to lay the foundation for the successful adoption and incorporation of industry 4.0 into the existing industrial framework by means of various policies.

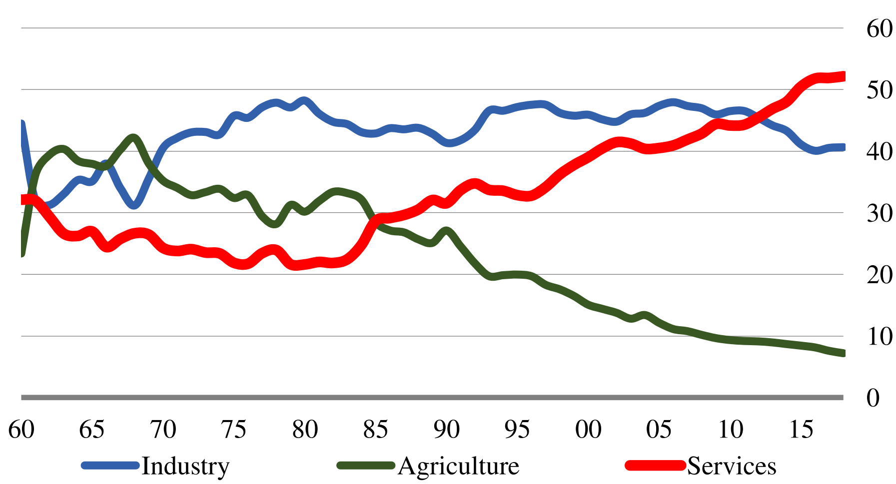

Fig. 7: Rapid structural transformation
Value added as % of total GDP, by sector, CN
(Source: World Bank, 2019) ***Insert "Fig7_VAShares_WB.xlsx"***

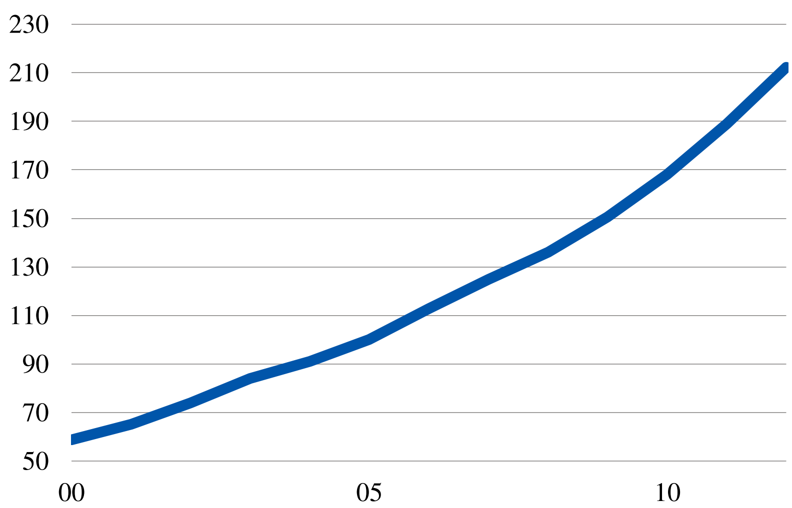

Fig. 8: Wages in manufacturing rise steadily

Real wages in manufacturing, CN, 2005=100

(Source: World Bank, 2018) ***Insert "Fig8_WagesCI_WB.xlsx"***

4.3. Impulses laid by politics

China's policy approach to industry 4.0 can be divided into three pillars. The first concerns the state's role in the creation of an appropriate environment in which industrialisation can take place. The second concerns the state's direct intervention in the process of industrialisation. Finally, the third pillar aims to gradually relocate the source of innovation from public institutes to private companies.

Several policy examples can be stated. For instance, fifteen years ago, China's State Council decided to accelerate the economy's technological progress via innovation, high-technology adaption and industrialisation by issuing the "Circular on policies for the development of software and IC industries". The program consists of policies spanning across all fields, including investment, financing, taxation, industrial technology, exports, income distribution, training, government procurement and intellectual property. China's industrial transformation was further facilitated in 2011 with the "Circular on the issuance of further encouraging the development of software and IC industry".

In the year 2012, the 18th Central Committee designated ICT-oriented development as one of China's key societal and economic goals until 2020. With the 12th Five-Year-Plan, high-tech companies are supposed to become main drivers of China's development. Specifically, the government highlights seven priority industrial segments. These sectors are new IT, high-end equipment manufacturing, biotechnology, energy conservation, new energy, new materials and clean-energy vehicles (see Nuernberg and Wang). To put this into perspective, the budget of the EU "Horizon 2020" program amounts to around EUR 80 bn for 2014 to 2020.

In the year 2015, China's State Council issued the "Made in China 2025" plan. The 10-year plan, which is inspired by Germany's "Industry 4.0" plan, has been compiled by more than 20 departments, 50 members of the Chinese Academy of Engineering and 100 other experts. It sets out to make innovation the core-competitiveness of an intelligent, digital and networked Chinese manufacturing industry and comprises the construction of a national manufacturing industry innovation centre. The plan reinforces the importance of Strategic Emerging Industries, highlighting a slightly modified and extended list of ten priority sectors. These sectors are: new advanced information technology, automated machine tools and robotics, aerospace and aeronautical equipment, maritime equipment and high-tech shipping, modern rail transport equipment, new-energy vehicles and equipment, power equipment, agricultural equipment, new materials as well as biopharma and advanced medical products. However, opposed to industrial five-year plans, the strategy "Made in China 2025" puts emphasis on a comprehensive upgrading of the economy's industrial structure.

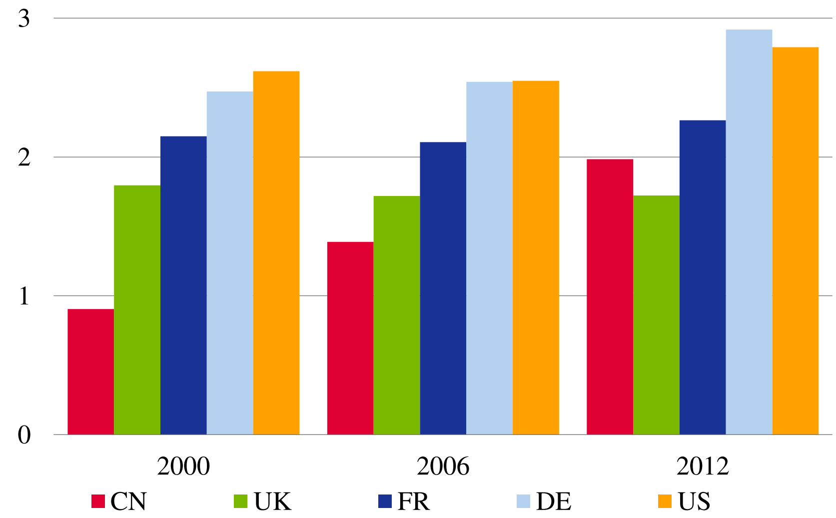

Fig. 9: China's increased spending on R&D

R&D expenditure as % of GDP

(Source: World Bank, 2018) ***Insert "Fig9_R&DDIV_WB.xlsx"***

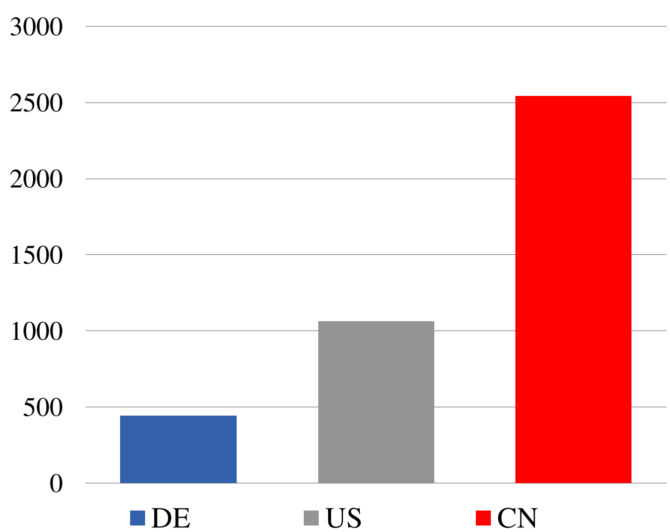

Fig. 10: China leads in patent applications

New priority patent application in the field of industry 4.0

(Source: Fraunhofer IAO, IAT, University of Stuttgart, 2015) ***Insert "Fig10_Patents_Fraunh.xlsx"***

4.4. Policies leads to first outcomes

Today, the outcomes of China's past policy actions are sizeable. According to McKinsey, the management consultancy, hundreds of midsize companies are creating a Chinese version of the German Mittelstand, with a focus on biotech, pharmaceuticals, consumer electronics, medical technology, drones and telecommunications equipment (see Orr). And they are getting more and more successful to become global market leader in their niches (Simon Kucher & Partners). The relative size of China's internet economy has not only caught up by international standards. Its share of 4.4% of gross domestic product (GDP) in 2013 also ranks the country among the global leaders, surpassing advanced economies such as the United States, France and Germany (see Woetzel et al.).

Improvements have been made on various levels, ranging from the formation of worker's technical skill capacity to patent applications and infrastructure development. More specific, the country surpassed the United States and Germany in terms of new priority applications for patents in the field of industry 4.0. China is now also the economy with the largest number of machine-to-machine connections (50 m), followed by the United States (32 m) and Japan (9.3 m) (see GSMA). In terms of expenditures in Research and Development (R&D), the country is on its way to reach its target to spend annually 2.5% of its GDP on R&D by 2020. The steady increase in the R&D expenditure share is particularly impressive given the large GDP growth rates in the last decade. In light of these numbers, it is not completely surprising that 57% of the executives interviewed in a survey published by Infosys, a business and IT consultancy, stated China to be the most mature adopter of industry 4.0, ahead of the United States (32%), United Kingdom (26%), Germany (21%) and France (14%) (see Infosys).

4.5. Highly heterogeneous regions

However, these numbers do not describe China of today completely. Clearly, China's manufacturing industry has made great achievements in fields like high-speed rail transportation equipment and telecommunication facilities. Companies such as Hisense (electronic hardware), Huawei (telecoms equipment), Lenovo (IT hardware), Mindray (medical equipment), Shinva Medical (medical equipment), Spreadtrum (semiconductor equipment), Xiaomi (smartphones), and ZTE (IT hardware) are among the world's leading innovators in their field, employing myriads of white-collar workers in their R&D departments.

At the same time, however, the majority of Chinese firms have not yet fully embraced the innovations related to past industrial stages. Many local firms are either reluctant or lack the financial capacity to invest in automation (see Terminio). McKinsey estimates that the internet adoption ratio of China's SMEs reaches only 25% (see Woetzel et al.). This means that, overall, digital unawareness is still particularly pronounced in this large group of companies, which together generate roughly 70% of China's GDP.

In addition, the reality is that most of the market leaders in the field of robotics and automation that produce in China are foreign companies, as for instance ABB, Comau, Fanuc, and Yaskawa (see Terminio). These firms generally form clusters in tech areas. These clusters are characterized by a well-established transport and ICT infrastructure. According to the Hong Kong Trade Development Council, there are more than 260 tech cluster in China today. Such cluster we find e.g. near Beijing, Chongqing, Shanghai, Tianjin or in particular in Shenzhen in the Hong Kong area. These agglomerations are extremely dynamic and innovative. Thus, in Shenzhen the average age of the 15 m inhabitants (for comparison, Hong Kong: 7 m) is 27 years (for comparison, Berlin: 43 y.). Besides, 15% of all unicorns[2] worldwide, or world market leader like WeChat (internet communication and payments), Tencent (gaming), DJI (drones), or BYD (e-cars) are located here – not in the directly nearby city Hong Kong. Lastly, all of 21.000 taxis and all of 16.000 urban buses are electrically driven.

Nevertheless, there is considerable heterogeneity between China's provinces, industries, companies and the workforce in terms of readiness and use of technology. Therefore, Industry 4.0 realizes locally and in an evolutionary fashion: factory-by-factory and company by company. Clearly, this makes it rather difficult to make a clear statement on the state of industry 4.0 in China, as the answer needs to be: "it depends". It depends on whether one looks at a single factory, company, value chain, industry cluster or the economy at large.

However, it is also evident that in order to repeat fully the benefits of industry 4.0, its implementation cannot be limited to a few companies. The gains to each company increase with the number of integrated industries and actors. To put it differently, in the context of industry 4.0, the total is larger than the sum of its parts – exponentially larger. From this standpoint, China's implementation of industry 4.0 is still in its infancy. Technological innovation and industrial upgrading have yet to trickle down to realize the vision of an innovation- and knowledge-driven economy. A long road lies ahead.

[2] Stat-ups with a worth of more than UDS 1 bn.

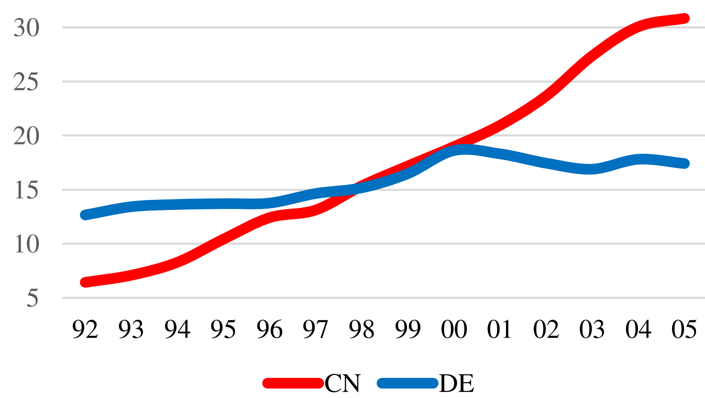

Fig. 11: China's high-tech exports increase in relative importance

High-technology exports[3], % of total manufactured exports

(Source: World Bank, 2018) ***Insert "Fig11_HightechExpShare_WB.xlsx"***

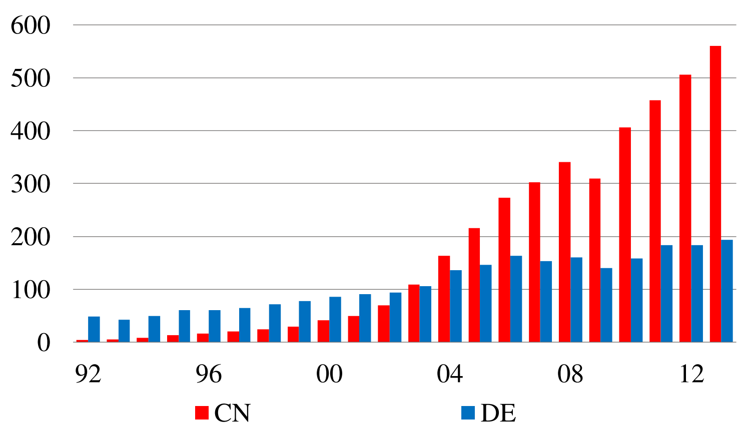

Fig. 12: China's high-tech exports increase in large absolute values

High-technology exports, USD bn.

(Source: World Bank, 2018) ***Insert "Fig12_HightechExpAbs_WB.xlsx"***

[3] High-technology exports are products with high R&D intensity, such as aerospace, computers, pharmaceuticals, scientific instruments, and electrical machinery.

4.6. Enable and facilitate company level action

A vital component of the digital evolution is a rapid and efficient data transmission within the value chain. This requires coordinated actions among various companies. However, the implementation and innovation of industry 4.0 at the company level are heavily influenced by the availability and accessibility of complementary (public) inputs. Clearly, a company can be constrained on its path to industrial upgrading by a lack of available advanced power grids and broadband connections. Unfortunately, complementarity creates problems of attribution. The question of who has to bear the costs for the provision of needed inputs will be closely linked to the transformation process.

A market revolution is prone to be accompanied by market failures and often call for state action. For instance, a key challenge of industry 4.0 lies in the productive use of collected data in real time. However, no company will bear the costs of countrywide high-speed broadband coverage. Companies are also reluctant to invest heavily in the quality of the workforce given the possibility of inter-company migration. At the same time, companies will lack incentives to build up other company capabilities needed to incorporate industry 4.0 into their production process, if either the ICT infrastructure or the skill-biased demand for labour is not met.

Unfortunately, there is no standard blueprint for the rollout of industry 4.0. The shape of concrete actions needed in terms of infrastructure investment, source of funding and time horizon depends on the conditions already in place. In an environment where the above stated constraints are severe a hybrid policy model is suited. Innovation will come from bottom-up approaches, while top-down policies address the problem of attribution and facilitate the process of industrial upgrading on the company level.

That said, the strategy “Made in China 2025” is based on four principles, which together indicate a reorientation in China’s policy approach. These principles are: market-oriented and government-guided, based on the present and having a long-term perspective, comprehensively pressing forward and making breakthroughs in key areas, independent development and win-win cooperation, according to Miao Wei, former Minister of the Ministry of Industry and Information Technology.

Hence, compared to the current industrial Five-Year Plan, “Made in China 2025” means a shift away from a rather narrow focus on selected Strategic Emerging Industries. The importance of the overall development of China’s economic society is recognized and highlighted. Beside this, the role of market institutions is stressed. Following the statements of highly ranked Chinese officials, this includes the dedication to create a fair environment that stimulates innovation and opening up much wider in terms of scientific and technological research from foreign initiatives. Explicitly, it highlights the dominant role of enterprises in technology innovation.

Next, despite the top-down policy approach, China’s seems to understand that cooperation is the key to complete the steps to an innovation-driven, high technology growth model that implements industry 4.0. Domestically, a council was established in 2013 to coordinate the government’s policy and action on the internet of things. Importantly, the council’s members include various public institutions, including the National Development and Reform Commission, the Ministry of Industry and Information Technology, the Ministry of Science and Technology, the Ministry of Education and the National Standardization Administration. However, also Chinese executives consider their voice heart by politics and regard a range of national public policies to contribute to their competitive advantage, according to a global CEO Survey by Deloitten, an advisory firm, and the U.S. Council on Competitiveness. This seems to be less the case in Europe and the United States.

4.7. Improving infrastructure

The ability to set up and use the latest available technology is a key factor for a comprehensive upgrading of an economy's industry, and ultimately for the implementation of industry 4.0. According to the Global Competitiveness Report (GCR) of the World Economic Forum (WEF), an international institution for public-private cooperation, China has still much room for improvements in this regard. While the number of people connected to the internet has risen considerably in the past, internet adoption has been mostly consumer-driven. Moreover, regarding internet bandwidth on average, China is still lagging behind.

Nonetheless, based on the policy targets, the government is determined to change the status quo (see Jia). The prerequisite of a modern ICT infrastructure is addressed by the National Broadband Plan. The plan aims to provide internet coverage at speeds of 20 Megabits per second (Mbit/s) in urban areas and 4 Mbit/s in rural areas. China's Government plans to spend USD 603 bn in the machine-to-machine ecosystem alone until the year 2020 (see See GSMA). To put this into perspective, the German government targets to connect every German household with broadband internet (50 Mbit/s) based on fibre-optic technology until 2018. The TÜV Rheinland calculates that the costs will amount to around USD 100 bn. (see See TÜV Rheinland).

It remains to be seen how ICT investments are regionally prioritized. Since the 12th Five-year-Plan, investments in strategic emerging industries are linked directly to a focus on single provinces. For example, the development of an industry for "clean energy vehicles" is concentrated in Beijing, Shanghai and Anhui, while the "new material" industry is focused on Shaanxi, Hunan and Liaoning (see Nuernberg and Wang). Although the "Made in China 2025" plan takes a more comprehensive approach, a sector focus remains. Hence, it is likely that public infrastructure investments will continue to foremost further upgrade regional industrial cluster.

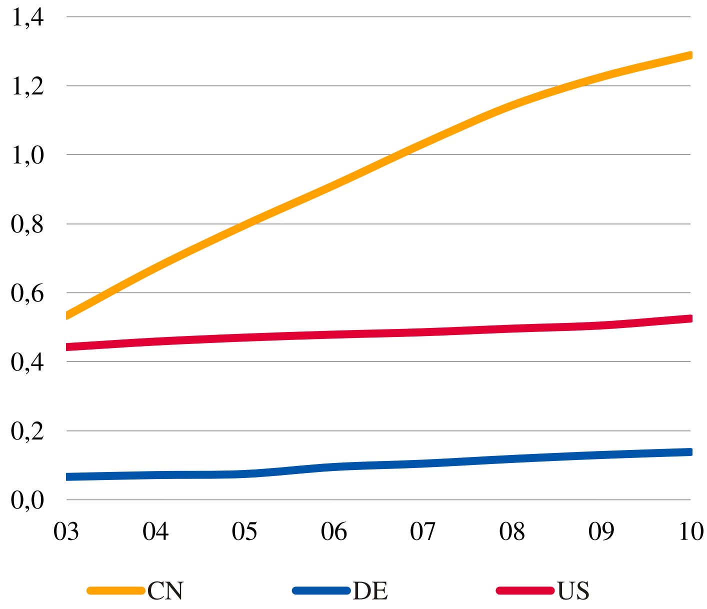

Fig. 13: Rapid academic increase:
Number first university degrees in science and engineering
(Source: National Science Foundation, 2014) ***Insert "Fig13_UniDegres_NSF"***

4.8. Challenging the quality of the workforce

Talent driven innovation is considered the most important driver in the Global Manufacturing Competitiveness Ranking (see Deloitte). Gearing people up with the skills they need to conduct the tasks demanded, involves improvements on various levels. It means boosting the ability to adopt an interdisciplinary mind-set, continuing to foster technical and analytical skill creation, as well as enabling and promoting lifelong learning. This can be achieved by improvements in the quantity and quality of formal education, as well as the availability of basic and advanced vocational training.

China presents a mixed picture in this regard. Undoubtedly, progress has been made in terms of school enrolment rates. Today, the enrolment rate in secondary education is about 90%, coming up from 58% in 2000.[4] Regarding tertiary education, the enrolment rate was only 8% in 2000 and increased to about 1/3 today. More specific, the number of graduates achieving a first university degree in the fields of science and engineering grew by 1/6 p.a. since 2000. Correspondingly, China awarded about 320,000 bachelor degrees in natural sciences and about 820,000 in engineering.

However, progress comes from a low level and the large absolute numbers of bachelor degrees in areas such as natural sciences and engineering mask the low average skill capacity per worker considering the country's enormous total workforce. Despite the improvements, the country still lacks behind in international comparison. In the GCR of the WEF, China is only ranked 72nd and 85th in terms of secondary and tertiary education enrolment rates. In addition, no progress has been made between 2000 and 2010 regarding the share of people in the age of 15 and above that completed tertiary education, which remains on a low level of 2.7%. Hence, the level of education of the workforce currently employed is still rather low. Further improvements in society-wide education are needed to avoid a severe shortage of skilled labour and to increase China's capacity to trickle down, adopt as well as invent new technologies on a wide scale.

4.9. Constructively addressing existing opposition

Chinese assembly lines today differ greatly from those of a decade ago. Over the years, the cost of technology that replaces labour in factories has plummeted, displacing more and more workers. As it is often the case, it is the most vulnerable sections of society that bear most of the

[4] The gross enrolment rates of schooling is the ratio of the total number of enrolled student in a certain level (primary, secondary or tertiary) divided by the population in the respective age-group (e.g. school-age or college-age).

costs. Automated processes will replace routine-based jobs, while augmenting analytical and technical skilled labour. However, it will also generate economic growth in aggregate terms. Numbers might help to address general opposition: McKinsey estimates that companies which adopted internet technologies created 2.6 jobs for each job lost (see See Woetzel et al.). In China, almost 1.5 million people have taken employment in express delivery and shipping businesses with the help of the rapidly growing e-commerce. Hence, industry 4.0 will enlarge the overall pie, while however also affecting its distribution.

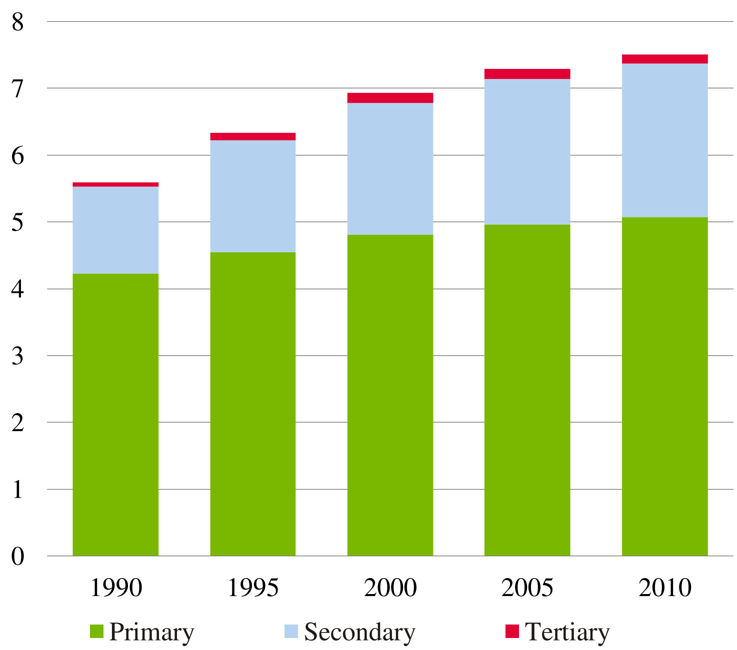

Fig. 14: Almost no progress in tertiary education
Average years of schooling, by education level, CN
(Source: Barro and Lee, 2013) ***Insert "Fig14_Schooling_Barro&Lee.xlsx"***

Addressing a potential shortfall in workers' capabilities via specific policy action has therefore two key benefits. On the one hand, it raises the quality and mobility of the workforce, and hence the awareness and support for industry 4.0 on an individual level. On the other hand, it motivates companies to invest in capabilities that promote the implementation of industry 4.0, which boosts efficiency and aggregate economic prosperity.

4.10. Ensure legal framework of data security and data protection

To facilitate innovations and information flows, currently unresolved issues concerning data security, confidentiality and standardisation need to be addressed. Interoperability and compatibility are essential for automation.[5] Efficient data transmission requires that interfaces and protocols are clearly defined. As long as different proprietary systems are incompatible with each other, it is extremely costly for a company to switch into a different value chain; and in some cases it is actually economically impossible. Standardisation is therefore a technical prerequisite.

The risks pertaining to data protection and data security are serious and constitute a concrete obstacle to the implementation of industry 4.0. Companies might abstain from a comprehensive integration into a value chain for fear of disclosing sensitive internal company data, if the links between supplier and customer become too close. More generally, the vast quantities of data uploaded and exchanged make users attractive targets for external attacks by hackers. Due to the increasing connectedness, such hacker attacks might then sabotage the entire production process, extending the level of risk from a company level to a macroeconomic dimension.

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[5] Interoperability is the ability of differing systems, technologies or organizations to work together. This usually requires compliance with common standards. If two systems can join, they can be described as being compatible.

A potential conflict arises between the national or regional character of the prevailing jurisdiction and the internationality of value chains. The concern that intellectual property becomes disclosed is fuelled by the fact that there are currently major geographical differences between legal provisions in terms of data protection and data security, in particular in the scope of data access granted to the government. The US Patriot Act as well as the Great Firewall in China provide two practical and explicitly formulated examples of challenges to balance between national interests and privacy rights in a more and more digitalized world.

The lack of data security can make the existence of patent protection obsolete. For instance, Elon Musk, the founder of the rocket company SpaceX, refuses patent technologies out of fear that foreign space agencies would simply pinch them. While such concerns prevail especially in some economically, military, and therefore politically important industries, they clearly display the dilemma of an increasingly integrated, digitalized, flat world.

The “Made in China 2025” strategy calls for strengthening intellectual property right protection for SMEs and stresses a more effective use of intellectual property in business strategy. Moreover, the plan discharges a top-down approach in terms of setting unique domestic standards and instead focuses on self-declared standards and the international standards system. This is a step in the right direction. It remains to be seen how the rhetoric is put into action. Inconsistent regulatory interpretation and unclear laws are ranked the second biggest business challenge in China according to the “China Business Climate Survey Report” published by the American Chamber of Commerce in the People’s Republic of China (AmCham China). Although 86% of the surveyed AmCham China member companies state that intellectual property law enforcement has improved, 78% also consider it to still be ineffective.

Further efforts are needed, so that a high degree of trustworthiness in the legal framework prevails and company property, tangible or intangible, is considered to be secure. Discrepancies between respective legal frameworks might otherwise constrain international trade and investment flows. Clearly, this cannot be achieved without close international cooperation between governments and institutions.

4.11. International cooperation on a level playing field

Aside from domestic policies, international cooperation plays a crucial part in the digital transformation of industries. It is encouraging to see that China has made a range of efforts to foster international agreements, despite the intense competition on the firm-level. For instance, the China-Germany Standardization Cooperation Commission deserves positive recognition. The commission is staffed with 40 representatives from the Chinese and German governments, DIN (German Institute for Standardization), Standardization Administration of the People's Republic (SAC), and further associations including acatech (Germany's National Academy of Science and Engineering) and Plattform Industrie 4.0 (a consortium promoted by the associations for electrical engineering (ZVEI), mechanical engineering (VDMA), and the ICT industry (Bitkom). A different example is the establishment of the first general standard in the context of the internet of things, initiated by China and passed by the International Telecommunication Union (ITU) in 2012. Moreover, the new standard was followed up appropriately by a joint White Paper issued by the EU and China last year in which the challenges for future developments are presented and various directions and development guidelines are discussed.

A crucial ingredient for industry 4.0 is to promote a bi-directional technology and knowledge transfer, which is mutually beneficial for all partners. China and Germany have laid a solid foundation in this regard. In 2014, China and Germany released their joint framework for action called “Innovation gemeinsam gestalten”. This framework stresses industry 4.0 as a central point for future bilateral economic relations.

The China-Germany “Industry 4.0 dialogue” and the “Deutsch-Chinesische Allianz für Berufsbildung” are great examples of how international cooperation can promote industry 4.0 in both countries even in areas such as workforce quality enhancement. The initiatives aim to promote the joint education of skilled engineering workers and therefore directly address the implications associated with industry 4.0.

5. Conclusion: Innovation creating a buzz

The concept of industry 4.0. inhabits the wide-ranging terrain occupied by augmented reality, Big Data, cloud computing, cyber-physical systems, RFID chips, Internet of things and services, machine-to-machine communication, precision farming, and Smart X. At present, the offerings associated with the industry 4.0 buzzword are definitely suffering from the excessive marketing-driven expectations and the lack of a clear definition. It is therefore certainly possible that following the hype which typically surrounds such new ideas and the subsequent disillusionment there will be no-one talking about industry 4.0 in a few years’ time. All the same, the basic idea behind the buzzword has a good chance of being implemented – regardless of the term used to describe it.

The application of industry 4.0 has largely been a matter for big companies. However, small and medium-sized companies are also finding that vertical and horizontal integration are becoming increasingly important factors in the competitive international arena. The wide range of benefits associated with industry 4.0 are being demonstrated by highly promising projects and prototypes from research institutes, such as DFKI, or Fraunhofer ISS/ EAS, Fraunhofer IOSB, and companies from as Agco and BorgWarner via Homag, HP, and Introbest throughout Trumpf, Volkswagen and Wittenstein in the western hemisphere; but also from Hisense and throughout Spreadtrum and ZTE in China..

The idea behind the buzzword industry 4.0 has good prospects that extend beyond the coming decade. With the international web of trade flows continuing to intensify, automation, more flexible processes as well as horizontal and vertical integration will become increasingly important for a competitive, modern manufacturing structure. This will apply even more if the currently still unresolved issues concerning control responsibility, security, confidentiality, standardisation, legal framework and infrastructure configuration (e.g. expansion of advanced power grids and communications networks) are addressed constructively.

Here, China is determined to seize the outstanding opportunity at hand. So far, not least due to the growth recession Chinas the government has laid a foundation by means of various policies. On first sight, the country appears to be in a good position in the race of the digital evolution. Hence, the country has set up world-leading high-technology manufacturers in the recent past and an emerging, highly innovative group of SMEs might actively participate in the digitalization of value chains. However, the great majority of companies still has to implement features related to past industrial stages. Many companies and workers are either unprepared or even unaware concerning the digital evolution. For a comprehensive upgrade of China’s economic structure and a thorough implementation of industry 4.0 promoting and integrating SMEs is a vital component. Only then will the country be able to sustain its transformation process and truly grasp the enormous benefits of a digitalized economy.

For a comprehensive upgrading and digital transformation of the Chinese industry further improvements in workforce quality and ICT infrastructure are urgently needed. With its “Made in China 2025” plan China maintains a top-down oriented hybrid (or dual-track) industrial policy approach to transform its economy through market forces as well as strong government interventions. However, overall, the new strategy leaves more room for company initiatives and further opens the door for foreign actors to participate on a level-playing field.

As the benefits of the digital transformation of the industry are likely to be not fully tangible until the next decade, patience is required. This ensures that actions are not only future-oriented, but also linked to a healthy portion of pragmatism. With the current plans, that combine a long-term vision with concrete actions in the present, the Chinese government is on the right track for upgrading the entire value chain.

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