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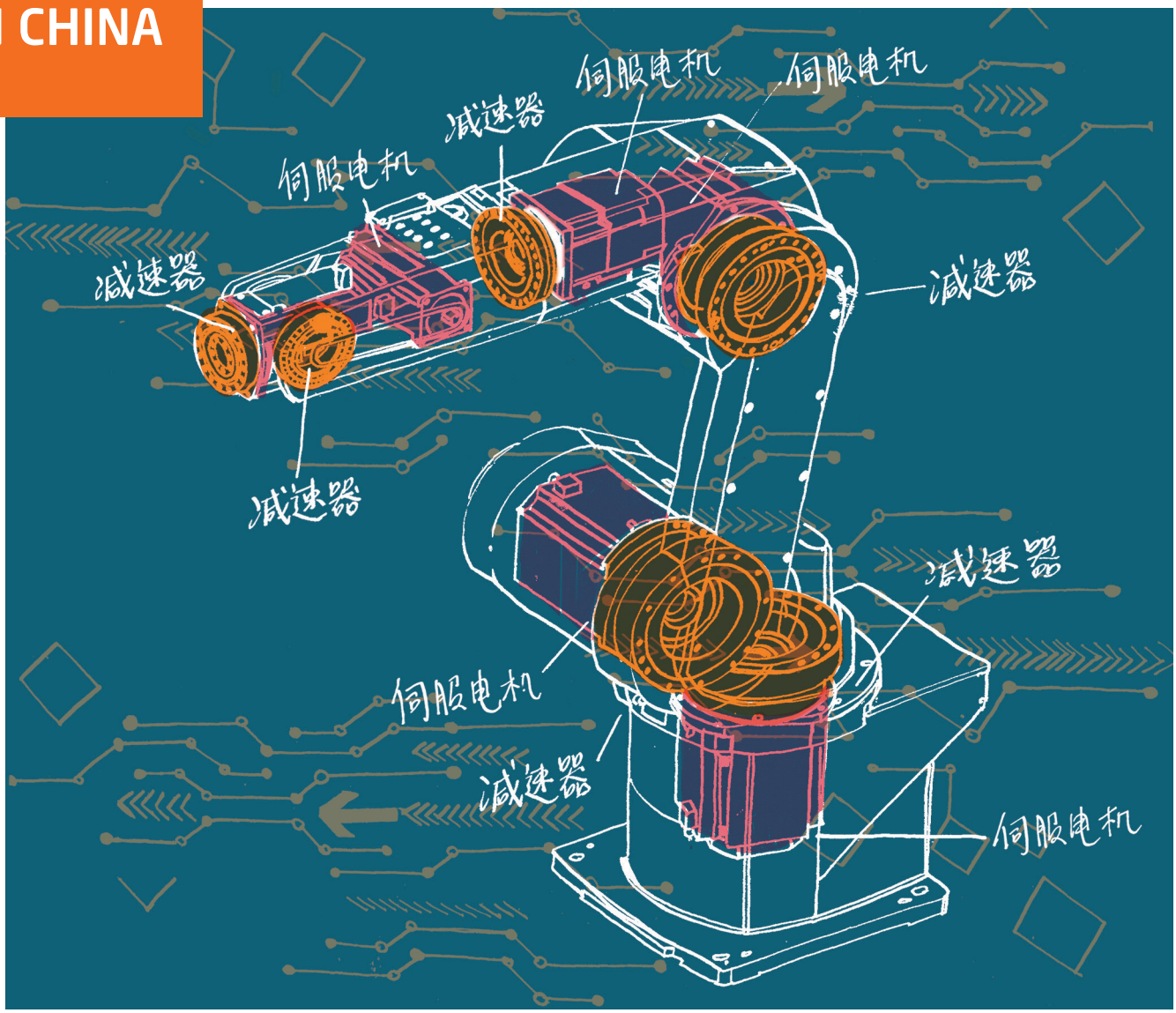

MADE IN CHINA 2025

The making of a high-tech superpower and consequences for industrial countries

Jost Wübbeke | Mirjam Meissner | Max J. Zenglein
Jaqueline Ives | Björn Conrad

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Executive Summary

CHINA'S INDUSTRIAL MODERNISATION: A CHALLENGE TO ADVANCED ECONOMIES

This report analyses China's ambitious plan to build one of the world's most advanced and competitive economies with the help of innovative manufacturing technologies ("smart manufacturing"). China's industrial masterplan "Made in China 2025" aims to turn the country into a "manufacturing superpower" over the coming decades. This industrial policy will challenge the economic primacy of the current leading economies and international corporations.

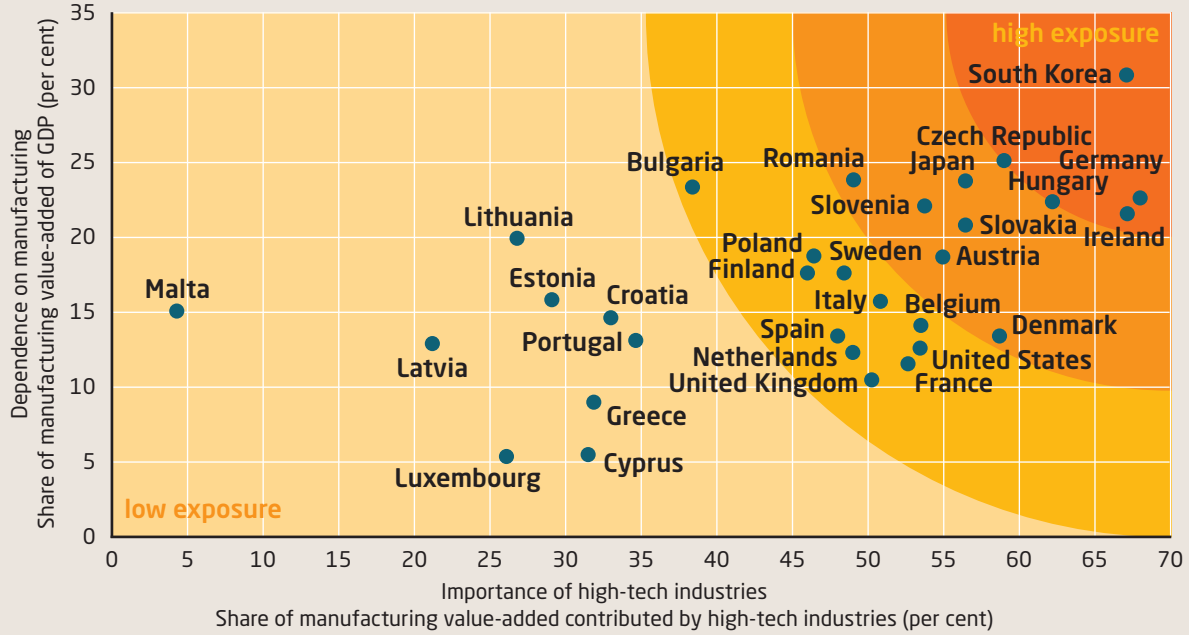
The strategy targets virtually all high-tech industries that strongly contribute to economic growth in advanced economies: automotive, aviation, machinery, robotics, high-tech maritime and railway equipment, energy-saving vehicles, medical devices and information technology to name only a few. Countries in which these high-tech industries contribute a large share of economic growth are most vulnerable to China's plans (see graphic below).

This report examines the repercussions of Made in China 2025 focusing specifically on smart manufacturing. The promotion and dissemination of smart manufacturing technology is the centrepiece of the strategy, borrowing from the German concept of Industry 4.0 and the Industrial Internet formulated in the United States. By energetically upgrading the mostly backward industrial processes of China's manufacturing sector, the Chinese government hopes to enhance the competitiveness of its enterprises on domestic markets and to propel their global expansion.

Figure 1

Under Pressure: Industrialised countries will feel the heat of Made in China 2025

Vulnerability of select industrial countries to Made in China 2025



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MADE IN CHINA 2025 CHANGES THE TERMS OF THE GAME

The political push for industrial modernisation in China creates an enormous demand for smart manufacturing products like industrial robots, smart sensors, wireless sensor networks and radio frequency identification chips. For many foreign enterprises, this initially provides highly attractive business opportunities: the transformation of China's manufacturing base requires advanced

technologies that Chinese suppliers are not able to provide at their current technological level. China's industrial upgrading, in the short-term, can mean tremendous profits for international companies. For China's economic partners in Europe and the United States, it could even open opportunities for a mutually beneficial deepening of economic, technological as well as political cooperation. In principle, the global economy has good reasons to welcome China's quest for increased innovation capacity, provided that China abides by the principles and rules of open markets and fair competition.

However, Made in China 2025 in its current form represents exactly the opposite: China's leadership systematically intervenes in domestic markets so as to benefit and facilitate the economic dominance of Chinese enterprises and to disadvantage foreign competitors. This is visible in smart manufacturing as well as in many other high-tech industries targeted by the strategy. In essence, Made in China 2025 aims for substitution: China seeks to gradually replace foreign with Chinese technology at home – and to prepare the ground for Chinese technology companies entering international markets.

Indications of this intention are omnipresent in Made in China 2025. The strategy stresses terms like "indigenous innovations" and "self-sufficiency". It intends to increase the domestic market share of Chinese suppliers for "basic core components and important basic materials" to 70 per cent by the year 2025. Semi-official documents related to the strategy set very concrete benchmarks for certain segments: 40 per cent of mobile phone chips on the Chinese market are supposed to be produced in China by 2025, as well as 70 per cent of industrial robots and 80 per cent of renewable energy equipment.

China seeks to gradually replace foreign with Chinese technology.

In order to achieve these goals, government entities at all levels funnel large amounts of money into China's industrial future. The recently established Advanced Manufacturing Fund alone amounts to 20 billion CNY (2.7 billion EUR). The National Integrated Circuit Fund even received 139 billion CNY (19 billion EUR). These national level funds are complemented by a plethora of provincial level financing vehicles. The financial resources are enormous compared to, for instance, the 200 million EUR of federal funding that the German government has provided for research on Industry 4.0 technologies so far.

While Chinese high-tech companies enjoy massive state backing, their foreign competitors in China face a whole set of barriers to market access and obstacles to their business activities: the closing of the market for information technology, the exclusion from local subsidy schemes, the low level of data security and the intensive collection of digital data by the Chinese state. As China's own smart manufacturing capabilities mature, it is likely that the Chinese state will further step up its discriminatory practices and restrictions of market access in the field of smart manufacturing.

At the moment, however, these barriers are not yet as established in smart manufacturing as in other areas such as the service sector and the aviation industry. Made in China 2025 is in its early days and there are still opportunities to adjust its direction and targets, at least in some sectors. If the incoming administration in the United States implements the protectionist agenda announced during the election campaign, Europe's negotiation position will potentially improve. Keeping global trade and investment flows open will become an overarching shared interest between Europe and China. Europe's economic importance for China will increase and vice-versa. Despite all current frictions, this mid-term shift in the global economy will potentially open new avenues for negotiating the conditions of Sino-European economic relations, including in smart-manufacturing.

TAKING OVER INTERNATIONAL HIGH-TECH ENTERPRISES

Made in China 2025 also has an outward-looking dimension: the accelerating acquisition of international high-tech companies by Chinese investors. To speed up China's technological catch-up and to leapfrog stages of technological development, Chinese companies are acquiring core technologies through investment abroad. In itself, this is neither surprising nor objectionable. However, China's technology acquisitions are partly supported and guided by the state. China pursues an outbound industrial policy with government capital and highly opaque investor networks to

facilitate high-tech acquisitions abroad. This undermines the principles of fair competition: China's state-led economic system is exploiting the openness of market economies in Europe and the United States.

Chinese high-tech investments need to be interpreted as building blocks of an overarching political programme. It aims to systematically acquire cutting-edge technology and generate large-scale technology transfer. In the long term, China wants to obtain control over the most profitable segments of global supply chains and production networks. If successful, Made in China 2025 could accelerate the erosion of industrial countries' current technological leadership across industrial sectors. As illustrated by the fierce discussions surrounding recent high-profile high-tech acquisitions, governments in Europe and the U.S. increasingly perceive this dimension of China's quest for technological upgrading as a crucial and pressing challenge.

WILL MADE IN CHINA 2025 SUCCEED? A MIXED PICTURE

Made in China 2025 will have a major impact on China's domestic as well as international markets. However, this report finds that the strategy is at the same time limited by a number of significant weaknesses, diminishing its scope and impact. The strategy is likely to succeed in elevating a small vanguard of Chinese manufacturers to a higher level of efficiency and productivity. These frontrunners are likely to dominate their sectors on the Chinese market and become fierce competitors on international markets.

Made in China 2025 is a forceful and smart challenge to the leading economies of today.

At the same time, Made in China 2025 will probably fail in its endeavour to catalyse a comprehensive, broad-scale technological upgrading across the Chinese economy. The strategy's effectiveness is limited by the mismatch between political priorities and industry needs, the fixation on quantitative targets, inefficient allocation of funding and campaign-style overspending by local governments. The lack of bottom-up initiative and investment is a pronounced weakness of Made in China 2025.

In addition, structural factors will further diminish the effectiveness of the policy: China's economy is currently experiencing downward pressure. Upgrading the production processes might result in job losses among the less skilled workforce. On the other hand, China's education system is not prepared for training skilled personnel capable of operating sophisticated smart manufacturing tools. As a result, the overarching goal of Made in China 2025, the deep transformation of China's entire manufacturing base, will most probably not be reached within the ambitious timeframe set by the Chinese leadership.

This is no reason for complacency. Despite its weak spots, Made in China 2025 is a reflection of China's sophisticated and strategic industrial policy. The strategy will rapidly increase the global competitiveness of key Chinese companies, selectively targeting the most important industries of the future. Made in China 2025 is a forceful and smart challenge to the leading economies of today. European and U.S. decision makers in politics and business will have to provide equally smart answers to this challenge.

Key recommendations

Decision makers in politics and business will have to identify adequate responses to the powerful Made in China 2025 strategy. The report formulates several courses of action to support effective responses (see chapter 7 for extended recommendations):

POLICY MAKERS

- **Rethink investment screening options.** Policy makers need to consider expanding their set of policy options to react to state-led acquisitions of high-tech enterprises. Plausible policy options include:
  - increasing transparency by tightening disclosure requirements for state-led acquisitions;
  - extending the scope of national security screenings;
  - deploying competition policy more broadly for reviewing state-owned investors;
  - establishing "reciprocity" measures to address and negotiate Chinese investment barriers;
  - screening state-led investments for systematic acquisition of essential high technology.
- **Implement a targeted industrial policy for crucial cyber technologies.** As a pro-active response to China's strategic industrial policy, European policy makers should set out to design and implement a narrowly targeted industrial policy themselves, focusing on strategic infant industries. Europe's cyber defence industry should be the top-priority for such promotional and protective policies. Public investment in European cyber defence businesses and start-ups would provide a much needed upgrade of protection against cyberattacks of state or non-state origin that carry increasing security, political and economic risks (i.e. beyond the risks of military sabotage: manipulation of democratic public opinion and elections, economic espionage, technology theft). EU and national governments need to thoroughly screen and, where necessary, prohibit foreign takeovers of cyber defence-related hardware and software companies on national security grounds.
- **Monitor and investigate potential WTO violations.** The European Union as well as the United States should investigate whether China's technology substitution strategy and specifically localisation targets (e.g. a minimum share of Chinese technology on domestic markets) violate the stipulations on local content requirements under the WTO treaties.
- **Seize emerging new avenues for negotiation.** If a protectionist shift in United States trade and investment policy becomes real, China will need Europe as a reliable partner in keeping global trade and investment flows open, and vice-versa. This provides European governments with new leverage in negotiating the conditions of Sino-European economic relations. European policy makers should be prepared to make effective use of this leverage.

INDUSTRY ASSOCIATIONS

- **Strengthen on-the-ground information gathering and sharing.** Decision makers urgently need more information on China's industrial policies applied in the context of Made in China 2025. Industry associations, through their presence on the ground, are in a strong position to improve information gathering on smart manufacturing policies in China.
- **Increase information through intensified dialogue.** Deepening exchange with Chinese smart manufacturing associations, industry partners and alliances as well as policy institutes will help provide early information about policy planning and implementation. In addition, regular dialogues can serve as a platform for discussing and solving technical issues that do not require decision making at the political level.
- **Use opportunities to influence standardisation processes.** The window of opportunity for influencing technological standardisation in China is still open. Foreign industry associations and large corporations should expand their activities and capacities in this regard.

SUPPLIERS OF SMART MANUFACTURING TECHNOLOGY

- **Prevent unidirectional technology transfer.** Increasing digitisation in combination with weak data security in China makes core technologies highly vulnerable. An effective method of protection would be to limit technical cooperation and digital integration to areas in which Chinese companies are already at an advanced technological level. These areas include 5G mobile networks, wireless sensor networks, 3D printing, industrial e-commerce, cloud computing and big data.
- **Act with caution regarding R&D activities in China.** If a loss of core technology to Chinese competitors seems possible, international enterprises should exclude critical knowledge and technologies from their R&D activities in China. This can minimise the risks of involuntary technology transfer.

MANUFACTURERS USING SMART MANUFACTURING

- **Avoid illusions about the technology gap.** Complacency is a major risk for advanced industries. Currently, European and American companies are still well advanced in the use of smart manufacturing in comparison to most of their Chinese competitors. But some Chinese companies will catch up quickly. To avoid being caught on the wrong foot, European and United States companies need to maintain their focus on their own technological advancement.
- **Coordinate for collective action.** International companies in China need to explore ways of building leverage to influence the Chinese leadership's decision making on industrial policy and cyber security regulations. Coordinating approaches among foreign companies, thus creating negotiating power through collective pressure, is one way of building leverage.

1. Smart manufacturing: China's chance to leap ahead in the global competition

Global industry is at the brink of the next technological revolution. The combination of intelligent machines, modern communication, big data and cloud computing is creating a disruptive change in industrial production. "Smart Manufacturing", "Industry 4.0" and "Industrial Internet" are different labels for this upcoming transformation. Governments and industries around the world recognise that this new technology paradigm will reshape the dynamics and rules of global competition. The race for advanced industrial production could decide the fate of large corporations and even the overall development of entire economies.

China sees this global race as an excellent opportunity to catch up technologically and economically with industrial countries. The goal is to become a global leader in manufacturing high quality and high-tech products by the first half of the 21st century and to substitute Chinese technology for foreign versions on domestic and global markets. Achieving this goal hinges on three factors: the ability to develop innovative products, to create internationally well-known brands and to build modern industrial production facilities. The leadership around Xi Jinping wants to use the third factor, industrial modernisation, in particular to boost China's international economic competitiveness. China understands well that the country's future economic progress and prosperity cannot be based on rusting factories and manual labour.

China is, however, in a poor starting position in the global race for smart manufacturing. The current level of automation and digitisation in China's industry is much lower than in industrial countries. China's government will make every effort to get ahead in the current transition towards smart manufacturing. In doing so, the leadership's instrument is a vigorous, comprehensive and ambitious industrial policy, embodied in the long-term strategy called Made in China 2025. Through this political initiative, China is channelling tremendous financial resources to support the technological upgrading of Chinese enterprises. This policy is already starting to create a boom in demand for technologies such as industrial software, sensor networks and robots.

China is channelling tremendous financial resources to support the technological upgrading of Chinese enterprises.

Based on a comprehensive assessment of the policy implementation process so far, this MERICS Paper on China concludes that in smart manufacturing the success of Made in China 2025 will be mixed. China's most ambitious goal of a broad-scale and economy-wide upgrading of industry within the next decade will very likely not be reached due to weaknesses in the design and implementation of the policy. Its broad catch-all approach does not meet the specific needs of many enterprises, allocation of funding is inefficient and local governments are overspending. In addition, contextual factors including downward pressure on China's overall economy, the latent impact of automation on the labour market and skill shortages significantly decrease the ability and willingness of most Chinese enterprises to invest in an expensive upgrading of production equipment.

While the political strategy is likely to miss its target of broad-scale industrial upgrading, it will be markedly successful in elevating essential parts of Chinese industry, creating a small but impactful group of global leaders in smart manufacturing. This report emphasises the catalysing effect of the policy on two distinct categories of enterprises:

Manufacturers. They employ automation and digitisation to improve the production of commodities such as cars, aeroplanes or refrigerators. Industrial policy will help to create or further elevate a small vanguard of Chinese manufacturers that will achieve a highly advanced level of efficiency and productivity through smart manufacturing within the next decade. These frontrunner manufacturers will successfully utilise modern production methods to considerably improve their competitiveness in domestic and international markets.

Technology suppliers for smart manufacturing. Tech suppliers produce, integrate and sell technologies needed for automation and digitisation such as robots, industrial software and Radio Frequency Identification (RFID) chips. Industrial policy will help to build a small number of highly advanced Chinese national champions that are able to supply state-of-the art technology. The tech suppliers will be increasingly capable of competing with leading foreign tech suppliers domestically and globally.

CHINESE TECHNO-NATIONALISM: A RISING CHALLENGE FOR INDUSTRIAL COUNTRIES

Even with mixed success, China's technology policy will create tremendous challenges for international corporations and entire economies of industrial countries. The economic advancement of China is principally positive and can create mutually beneficial opportunities for China and its economic partners. It would be unproductive to perceive China's technological rise as a zero-sum game in which increased Chinese strength directly weakens other industrial countries. However, it is a valid concern that the active industrial policy by the Chinese state results in an uneven playing field in which foreign competitors are at a disadvantage.

Chinese frontrunner manufacturers and their advanced production lines will increase the global competitive pressure in high-tech industries, for instance in electronics and machinery. They will actively challenge the leadership of foreign manufacturers in the very industries that represent the key pillars of economic prosperity in many industrial countries.

Foreign tech suppliers will initially greatly benefit from the smart manufacturing boom in China. China is currently still highly dependent on foreign technology to implement its ambitious upgrading plans. However, these market opportunities will sharply diminish within the next decade. Chinese tech suppliers will become more sophisticated and will improve their products with the help of political support and protection. The Chinese state also increasingly pushes its tech suppliers and manufacturers to acquire essential technologies abroad in order to close the technology gap. These state-led foreign direct investments (FDI) could contribute to a hollowing out of the technological lead of industrial countries.

Chinese frontrunner manufacturers will increase the global competitive pressure in high-tech industries.

Enterprises, business associations and governments in Europe will now have to respond to the challenges of Chinese technology nationalism in manufacturing. The potential consequences of European political and industrial inaction arising from complacency about Europe's advanced level of production and underestimation of the Chinese catch-up process are severe. For that reason, this report aims to present the characteristics of Chinese industrial policy on automation and digitisation as well as the challenges and options for European stakeholders.

The report is based on an extensive examination of Chinese-language sources including policy documents, expert journals and newspaper articles. The authors interviewed more than 60 experts from enterprises, associations and political positions during field research in China and Europe. Additionally, the report is complemented by quantitative analyses of patent activities, subsidies and other categories.

The analysis will start with the paramount role of Made in China 2025 for industrial upgrading in China (Chapter 2). It then illustrates the advantages and limitations of this policy in catalysing the broad-scale application of smart manufacturing throughout the Chinese industrial sector (Chapter 3). Chapter 4 will show how smart manufacturing strengthens Chinese manufacturers. Chapter 5 assesses the trajectory of the increasing competitiveness of Chinese tech suppliers. The report will conclude with an overview of challenges for the economies and enterprises of industrial countries (Chapter 6) and will provide recommendations for European stakeholders in politics and business (Chapter 7).

CONCEPTS AND KEY TERMS: SMART MANUFACTURING, INDUSTRY 4.0 AND INDUSTRIAL INTERNET

Smart manufacturing refers to the use of automation and digitisation technology in industrial production and organisation. Historically, the innovation of production technologies has caused leaps in productivity and disruption in existing market structures. Industrial development has undergone three major revolutions:

- the 1st revolution in the late 18th century ("Industry 1.0"): mechanical production driven by steam and water power;
- the 2nd revolution in the late 19th century ("Industry 2.0"): electrification of machines and mass production;
- the 3rd revolution in the 1970s ("Industry 3.0"): industrial robots, programmable logic controllers and IT-based production management.

Production in industrial countries today mostly uses the tools and systems of the third revolution. Currently, a potential fourth disruption to global manufacturing, often called Industry 4.0 or Industrial Internet, is predicted. This technological change is characterised by the combination of advanced internet and communication technologies, embedded systems and intelligent machines.

In so-called Cyber-Physical Systems, connected machines collect massive amounts of data through smart sensors, communicate with each other and independently make decisions. These systems create and analyse big data to optimise production processes and logistics. Whereas the German term Industry 4.0 emphasises engineering, the American Industrial Internet focuses more on the software-related elements of smart manufacturing. Industry 4.0 and the Industrial Internet are supposed to increase productivity by reducing idle times, improving predictive and preventive maintenance of equipment and making logistics more efficient. Moreover, the software integration of manufacturing execution systems (MES) and customer relations management (CRM) should increase the flexibility of production and the degree of customisation (mass customisation).

The terms Industry 4.0 and Industrial Internet should be used with care as both concepts have also attracted some criticism. These terms are also marketing vehicles to better promote new products for application in industry. Most importantly, Industry 4.0 and Industrial Internet still have to prove whether they really can deliver a fourth revolution. This report uses these terms only to refer to the relevant technologies and potential applications that lie behind them.

The concept of advanced manufacturing used in this report is much broader than Industry 4.0 and the Industrial Internet. Chinese industry currently still uses the tools and systems of the second industrial revolution and has only begun to embrace the third revolution. Chinese enterprises are only starting to use technologies which are already widespread in industrial countries. The Chinese definition of smart manufacturing often mixes the third industrial revolution with Industry 4.0 and the Industrial Internet.

In line with the Chinese understanding, this report adopts a broad definition of smart manufacturing. This includes technologies of the third industrial revolution, such as traditional industrial robots, industry software and computerised machine tools, as well as cutting-edge production technologies, such as wireless sensor networks, intelligent robots and integrated software processes. This report only uses the term Industry 4.0 in cases where it explicitly seeks to demarcate the most advanced technological level from the third industrial revolution.

2. Made in China 2025: a master plan for industrial leadership and import substitution

KEY FINDINGS

- Starting from a very low level, China's industrial production technology is currently experiencing rapid growth in smart manufacturing.
- However, bottom-up enterprise initiatives in advanced production technology are generally still weak and do not explain the current boom.
- Instead, China's top-down industrial policy is the main driver behind smart manufacturing in China.
- The Chinese leadership sees smart manufacturing as a key tool for challenging the technological dominance of industrial countries and simultaneously defending China's low-end industries against growing competition from developing countries.
- A central goal of Chinese industrial policy on smart manufacturing is to gradually substitute foreign technology with Chinese versions.

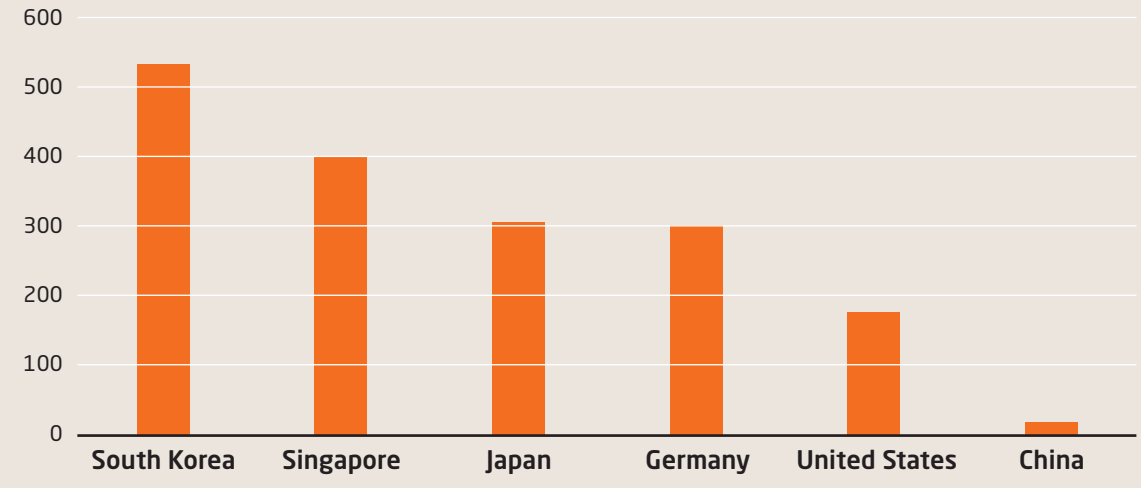
China's industrial production is still backward compared to industrial countries. Most Chinese factories feature a rudimentary level of automation and almost no digitisation. For instance, Chinese enterprises utilise an average of just 19 industrial robots per 10,000 industry employees. This compares to 531 in South Korea, 301 in Germany and 176 in the United States (Figure 2).[1] Labour productivity is several times lower than in industrial and even some developing countries (Figure 3). Technology leaders such as Germany and Japan, in contrast, make intensive use of production lines and management processes based on modern information technology and highly automated machines.

Starting from a low level, Chinese industry is currently experiencing a rapid increase in demand for automation and digitisation technology. Chinese enterprises mostly demand basic tech-

Figure 2

Automation in China's industry is low

Density of industrial robots per 10,000 workers in 2015



Source: IFR, data for China adjusted by MERICS

nologies that have been in use in industrial countries for a long time. Market growth for typical Industry 3.0 technologies such as industrial software, traditional industrial robots and industrial sensors was between 10 and 25 per cent in 2015. But market figures also demonstrate that China's industry has already started to invest in technology relevant to the next generation of industrial production (Industry 4.0). For instance, demand for big data, cloud computing, wireless sensor networks (WSN) and microelectromechanical systems (MEMS) grew by 20 to 25 per cent in 2015.[2]

2.1 POLITICS, NOT BUSINESS: THE REAL DRIVER BEHIND CHINA'S SMART MANUFACTURING BOOM

China's economy is in urgent need of a new innovation-driven growth model.

The smart manufacturing boom in China is mainly not driven by bottom-up enterprise initiatives. Most Chinese enterprises are reluctant and risk-averse when it comes to investing in high-tech equipment for production. The managers of the enterprises rather opt for low-cost and good-enough solutions with low upfront investment. Apart from a few frontrunners, enterprise initiatives tend to be weak when compared to other countries. According to a survey, 21 per cent of Chinese enterprises state that they are testing or using Industry 4.0 applications (the corresponding figure for German enterprises is 40 per cent).[3]

Most Chinese enterprises feel no pressure to undergo a lengthy and costly upgrade toward modern production capacity. Firstly, many enterprises are not exposed to the pressures of free market competition in an economy that is characterised by intense state interference. They lack the incentives to strengthen market power by increasing productivity and improving production technology. Instead, many enterprises can rely on political protection to achieve market dominance.

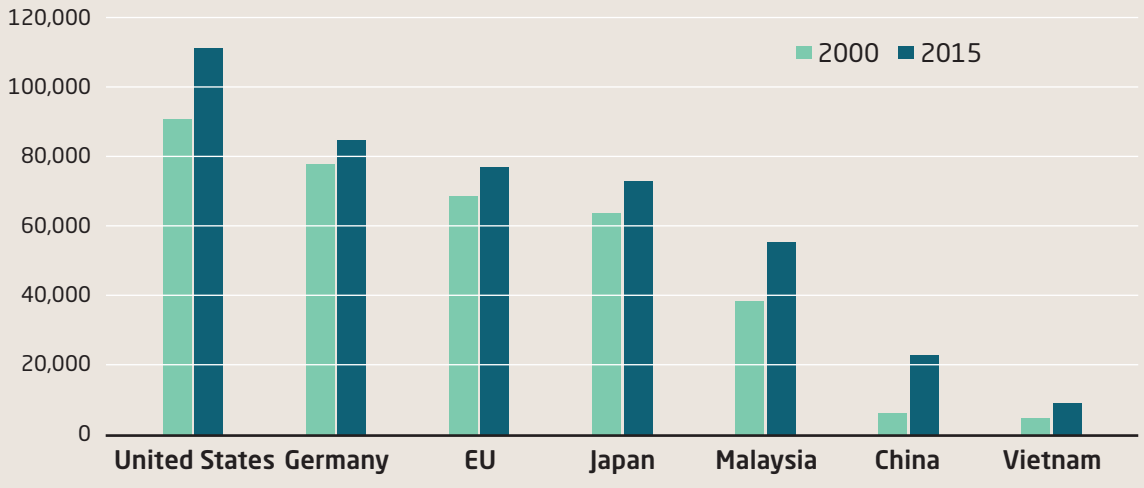
Secondly, Chinese manufacturing labour costs and minimum wages are increasing, but they are still moderate and only slightly higher than in neighbouring Southeast Asian countries (Figure 4). Employing a large workforce often still represents the cheaper option compared to major investment in new equipment. While local labour shortages characterised the period following the global economic and financial crisis in 2008, Chinese manufacturing now once more has a surfeit of workers with low and medium skills.

Several factors are beginning to gradually change the cost-benefit calculation of Chinese enterprises as they are slowly moving towards more investment in high automation. For some labour-intensive industries such as garment production and in some localities such as the Canton-

Figure 3

Chinese productivity is low

Labour productivity in selected countries (GDP per employee, constant 2011 PPP in USD)

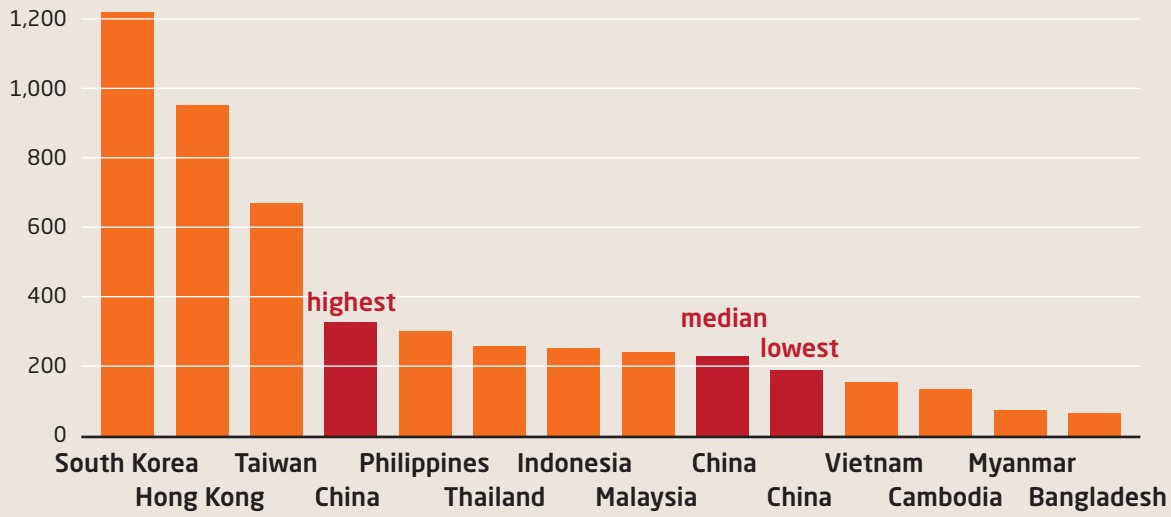


Sources: World Bank, MERICS

Figure 4

Labour costs in China are still moderate

Minimum wages in Asia in USD per month as of September 2016 (highest prevailing minimum wage)



Source: MERICS

ese city of Dongguan, wage pressure is already relatively high. This pressure provides an incentive for enterprises to spend more on automated machines. In addition, factory planners increasingly substitute robots for workers who are no longer willing to undertake stressful tasks such as varnishing, welding and polishing, even if they are well paid. But across China's manufacturing sector, these trends are not widespread enough to lead to a decisive and broad upgrading of Chinese manufacturing technology.

An advanced industry: a key tool for escaping the middle-income trap

While enterprises are still hesitant, the Chinese government is the main driving force behind the smart manufacturing boom in China. Prime Minister Li Keqiang stated that "the manufacturing industry is a main pillar for the national economy, main opportunities must be used. The transition towards smart manufacturing is essential".[4] China's political leaders see a modern industry as an important ingredient in solving the country's overarching economic challenge: China's economy is in urgent need of a new innovation-driven growth model.

The goal is to build an economic structure and capabilities similar to that of Germany and Japan.

The push for smart manufacturing is closely associated with China's reform agenda to revamp the basic structures of its economy and adapt to future needs. The agenda, adopted at the third plenum of the 18th Central Committee of the Communist Party in 2013, listed reforms in areas such as state-owned enterprises, fiscal policy, financial system and market access for foreigners. However, progress is so far mixed and original promises of liberalisation, such as in the state-owned sector, turned out to be illusionary.

Without important change in the economic system and the modernisation of its industry, the country risks being stuck in mediocrity between industrial and developing countries. As expressed in the Made in China 2025 strategy, "China's manufacturing industry faces the serious challenge of a 'double pressure' between industrial and other developing countries". Advanced manufacturing is expected to help China to address this double pressure.

Firstly, the aim is to challenge the market dominance of industrial countries. To avoid the middle-income trap, China is seeking to make a leap forward towards becoming a leading "Manufacturing Superpower" (制造强国) and "Internet Superpower" (网络强国). The goal is essentially to build an economic structure and capabilities similar to that of Germany and Japan: a strong industrial country based on a robust and innovative manufacturing industry. Modern production

facilities will be the key to achieving the same level of productivity and product quality as found in established industrial countries.

Secondly, China's leaders seek to defend the country's status as the "factory of the world" for low-value industries against developing countries. Wage increases have not yet caused large-scale offshoring, but the Chinese leadership sees the relocation of factories to Southeast Asian neighbours as a serious medium-term threat. Reshoring to industrial countries, as demonstrated by the recent re-opening of a highly automated Adidas shoe factory in Germany and reindustrialisation in the U.S., is a growing issue. With automation and digitisation of industry, the Chinese government wants to maintain the advantage of low manufacturing costs in industries such as textiles.[5]

2.2 TOP-DOWN STRATEGY PUSHES SMART MANUFACTURING

The government is seeking to attain its goals through political campaigning and financial support. In 2015, China's government initiated a very comprehensive, forward-looking and smart master-plan for economic and industrial modernisation: Made in China 2025 (**中国制造**2025). The strategy builds on decades of industrial policy making. It is not radically new but it is larger in scope and backed up with greater resources than past industrial policies. It integrates a great number of previously largely uncoordinated efforts to promote smart manufacturing.[6] On this basis, the long-term plan looks far into the future, boldly and ambitiously outlining China's technological development path until 2049, with 2025 merely representing an intermediary step.

Made in China 2025 goes far beyond the scope of comparable strategies for industrial digitisation in other countries.

Made in China 2025 is strongly inspired by Germany's Industry 4.0 strategy. The Chinese Academy of Engineering embraced the German concept when drafting its "Manufacturing Superpower" report in 2013. The report served as a scientific foundation for the formulation of Made in China 2025.[7] Following the Academy's report, the political leadership kicked off an energetic campaign in 2014. President Xi Jinping, Prime Minister Li Keqiang and Deputy Prime Minister Ma Kai made important comments on Industry 4.0 and paid and received several state visits to and from Germany revolving around cooperation on this topic.

Made in China 2025 is a top-down strategy. The leadership imposes its policy priorities and strategic vision for industrial upgrading on a manufacturing industry that has so far been largely hesitant about industrial modernisation. This strong role of policy as the driver of smart manufacturing development stands in stark contrast to the pivotal role of enterprise initiative in the bottom-up process in Germany, the United States and many other countries.

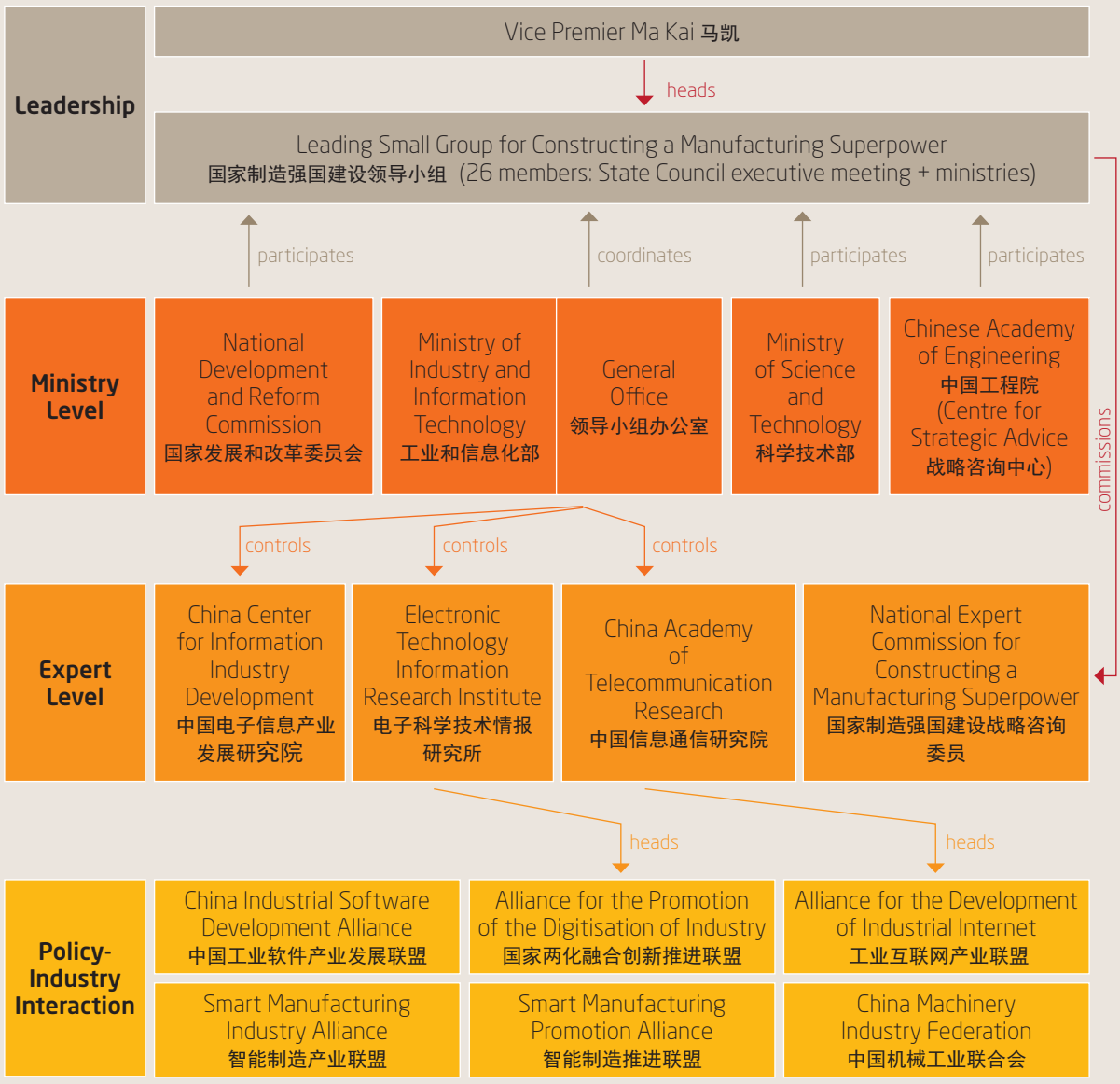
The high political relevance of Made in China 2025 is also reflected in powerful institutional backing for smart manufacturing. The inter-ministerial Leading Small Group for Constructing a Manufacturing Superpower, headed by Deputy Prime Minister Ma Kai, is responsible for macro-strategic planning and coordination (Figure 5). The Ministry of Industry and Information Technology (MIIT), China's powerful administration for industrial policy, is tasked with the implementation of the policies.

Made in China 2025 goes far beyond the scope of comparable strategies for the automation and digitisation of industry in other countries. The plan embodies a comprehensive and strategically interlinked battery of industrial policies, geared towards the overall goal of turning China into a "Manufacturing Superpower". This goal applies in particular to ten high-tech industries such as the automotive industry and energy equipment. Besides smart manufacturing, Made in China 2025 also includes provisions on innovation in manufacturing, product quality management and sustainable production (Table 1).

As for smart manufacturing, the plan is to upgrade production technology across the entire industry: large- and small-scale, state-owned and private enterprises. Important tasks are the commercialisation of smart manufacturing technologies, the application of smart manufacturing in key enterprises, the construction of intelligent factories and the development of service-oriented manufacturing. In particular, high-end computerised numeric control machine tools, industrial robots and advanced IT are the focus of the plan.

Figure 5

Smart manufacturing is high on the agenda
Political organisations behind Made in China 2025



Source: MERICS

Table 1

Industrial policy for technological progress
The main targets of Made in China 2025

Indicators	2013	2015	2020	2025
Innovation				
Share of R&D spending of operating revenue (in %)	0.88	0.95	1.26	1.68
Invention patents per 100 million CNY total revenue	0.36	0.44	0.7	1.1
Quality				
Quality competitiveness index*	83.1	83.5	84.5	85.5
Growth of industrial value-added (in %)	9.7	5.9	7.9	9.9
Productivity growth (in %, annual average)	7.3	6.6	7.5	6.5
Digitisation of Industry				
Broadband internet (penetration in %)	37	50	70	82
Use of digital design tools in R&D (penetration in %)	52	58	72	84
Use of numerical control machines in key production processes (penetration in %)	27	33	50	64
Environmental Protection				
Decrease in industrial energy intensity (in % compared to 2015)	-	-	-18	-34
Decrease in CO2 emission intensity (in % compared to 2015)	-	-	-22	-40
Decrease in water usage intensity (in % compared to 2015)	-	-	-23	-41
Reuse of solid industrial waste (in % of total waste)	62	65	73	79

Key technologies targeted by Made in China 2025

- New generation information technology
- High-end computerised machines and robots
- Space and aviation
- Maritime equipment and high-tech ships
- Advanced railway transportation equipment
- New energy and energy-saving vehicles
- Energy equipment
- Agricultural machines
- New materials
- Biopharma and high-tech medical devices

Notes: *accumulated indicator based on data from 250,000 enterprises; criteria include current implementation of quality management and supervision as well as potential for future quality improvements

Source: State Council, National Bureau of Statistics

THE ROLE OF INTERNET PLUS FOR SMART MANUFACTURING

The Chinese government is seeking to integrate Made in China 2025 with China's digital agenda, the Internet Plus plan. Internet Plus is a full-blown plan to digitise the economy and society beyond the traditional internet. It seeks to create new information technology solutions in areas such as health, finance, education and transport, referring tangentially to issues of smart manufacturing. The technologies which Internet Plus is intended to promote will be relevant for industrial production as well. These comprise cloud computing, big data, the internet of things and e-commerce. Despite this overlap with Internet Plus, Made in China 2025 is the main strategy for developing smart manufacturing in China.

In contrast to the top-down approach of Made in China 2025, Internet Plus is based on bottom-up initiatives by internet enterprises. Ma Huateng, CEO of the internet giant Tencent, formulated the "Internet Plus" concept in 2014, and Li Keqiang picked up the term in his government report in 2015. Internet enterprises are closely involved in drafting implementation guidelines for the Internet Plus strategy.[8] At the central government level, the National Development and Reform Commission (NDRC) is responsible for implementing the strategy.

2.3 CHINA'S AIM IS TECHNOLOGY SUBSTITUTION

China's industrial policy in manufacturing and digitisation ultimately aims to achieve technological catch-up and import substitution. The political leadership intends to gradually substitute foreign technology with Chinese technology (localisation). Chinese high-tech industries, in particular the national champions, are expected to acquire the capabilities to create independent innovative technological solutions and replace their foreign competitors on the domestic market and increasingly also on global markets.

Words like "indigenous innovations" and "self-sufficiency" are omnipresent in Made in China 2025.

The objective of technological progress and substitution thoroughly penetrates Made in China 2025. On an abstract level, the plan stresses the need to "strive to control essential core technology, improve industrial supply chains and build independent development capacities in basic, strategic and comprehensive areas related to the national economy and industrial security". Words like "indigenous innovations" (自主创新) and "self-sufficiency" (自主保障) are omnipresent in the document. The plan states the need to develop and use indigenous products in fields such as computer-aided design tools, industrial platform software, smart manufacturing technology and electric vehicles.[9]

The main document of Made in China 2025 contains few concrete targets for Chinese products. One specific goal is, for example, to increase the domestic market share of Chinese suppliers for "basic core components and important basic materials" to 70 per cent. Several supplementary semi-official documents including the "Made in China 2025 Key Area Technology Roadmap", however, propose specific targets for the market share of home-grown technologies (Figure 6).[10]

The MIIT insists that Made in China 2025 will not adopt a new system of local content. It states that the "Made in China 2025 Key Area Technology Roadmap" containing many of these targets is a scientific document, produced by 48 academics of the Chinese Academy of Engineering and over 400 experts, and has no policy implications. However, Vice-Premier Ma Kai has officially endorsed the document, illustrating the political weight of the roadmap.

To avoid an open violation of WTO obligations, it appears that the responsible ministries and state-owned policy institutes use internal or semi-official documents to communicate local content targets to Chinese enterprises in industries such as aviation and electric vehicles.[11] The Chinese government could so far not eliminate concerns of foreign governments and enterpris-

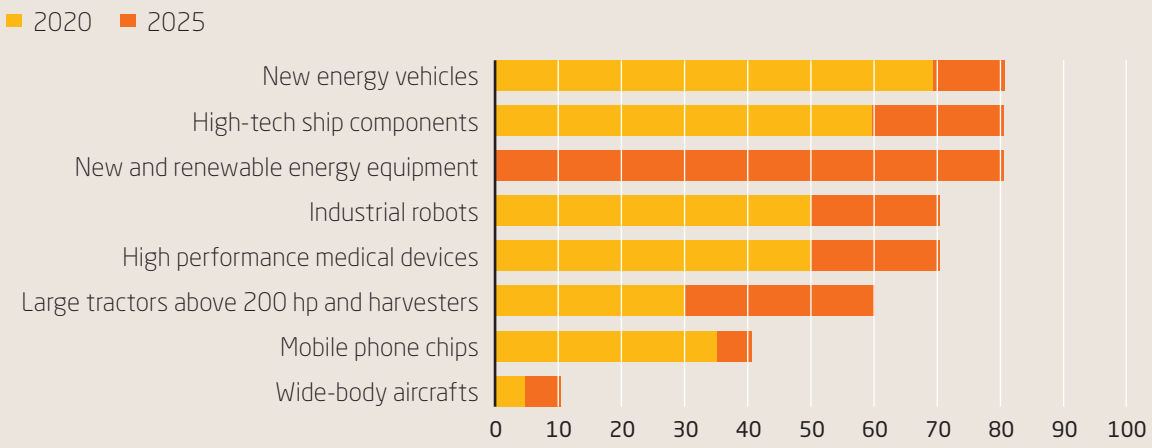
es that China is building an informal system of local content targets. A letter from the German ambassador in China to MIIT minister Miao Wei inquiring about localisation targets for electric vehicles remained unanswered so far.[12]

In China's general industrial policy, the localisation targets are implemented using broad and diverse measures. The government subsidises Chinese products while excluding foreign alternatives, for example, in the fields of electric vehicles and – to a certain extent – robotics. The government also supports Chinese enterprises with direct capital injections and preferential loans in many industries such as steel and machinery. National investment funds such as the National Integrated Circuit Investment Fund (National IC Fund) in the semiconductor industry directly invest in enterprises. In other cases, the state closes the public procurement market to foreign enterprises, for example in information technology. In the past, the government has also set local content requirements as conditions for carrying out public projects, for example in the wind industry.

Figure 6

Made in China 2025 aims at substitution

Semi-official targets for the domestic market share of Chinese products (in per cent)



Source: Expert Commission for the Construction of a Manufacturing Superpower

3. Strengths and limitations of Made in China 2025

KEY FINDINGS

- Major strengths of the policy initiative include its mobilisation capacity, long-term planning, generous funding, local experimentation and strong local initiatives.
- Weaknesses include the mismatch between political priorities and industry needs, the fixation on quantitative targets, inefficient allocation of funding and overspending by local governments.
- Contextual factors, most importantly the overall downward pressure on China's economy, the possible effects of upgrading on the labour market and the shortage of skilled labour, will diminish the effectiveness of the policy.
- The policy will not lead to wide-ranging industrial upgrading nor will it create a broad-based industry of tech suppliers within the next decade.
- But the initiative will succeed in building a small, highly competitive group of manufacturers and tech suppliers of smart manufacturing, significantly enhancing China's economic competitiveness in domestic and global high technology markets.

The great vision for China's industrial future looks impressive on paper. Made in China 2025 appears to be a smart and comprehensive plan to promote technological progress in manufacturing. The political programme, however, will still have to prove whether it can be effective in practice. Made in China 2025 is a broad and general framework that needs further specification. The implementation is just beginning. Careful analysis of upcoming implementation documents and industry-specific five-year plans is necessary to further evaluate the direction and outcomes of government policy (Figure 7; a list of the policies can also be found in the annex). The examination of implementation steps taken since 2015 allows for predictions of likely outcomes and impacts.

China will fail to catalyse a broad industrial upgrading within the next decade.

China has very powerful policy instruments at its disposal that create a significant and immediate dynamic on the ground. Yet policy strengths go hand in hand with inherent weaknesses that hinder successful implementation. This chapter will show that, on balance, China is likely to miss some of its goals but achieve others: it will almost certainly fail to catalyse a broad, economy-wide industrial upgrading of Chinese manufacturers within the next decade and it will also be unsuccessful in building a broad-based, highly competitive industry of tech suppliers for smart manufacturing within the given timeframe.

China is more than likely to succeed in creating a small, powerful group of national champions among manufacturers and tech suppliers. These champions will play a dominant role in their respective domestic markets and will grow into formidable international competitors.

3.1 POWERFUL INSTRUMENTS FOR IMPLEMENTATION

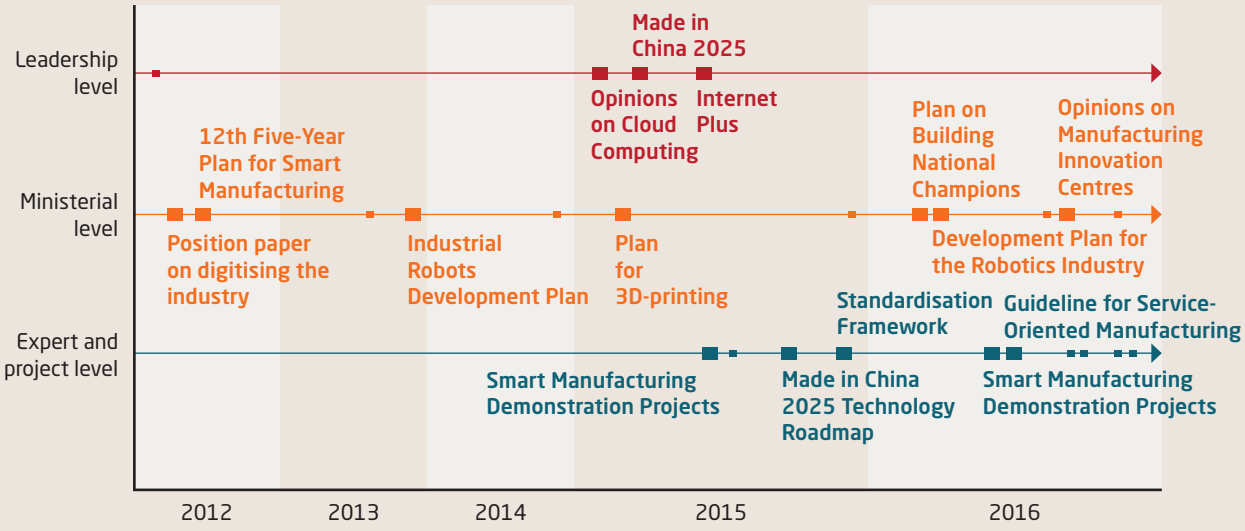
Massive mobilisation capacity

On the positive side, the mobilisation capacity of China's policy campaign is substantial. The particular strength of top-down policies is that they attract widespread attention throughout the country in a short time. After Made in China 2025 was released in 2015, discussion on smart manufacturing spread in China's industry and the wider public. Industry 4.0 and smart manufacturing rapidly turned into popular buzzwords for describing China's path to technological modernisation. The number of scientific and expert articles mentioning "Industry 4.0" increased fivefold between 2014 and 2015.[13]

Figure 7

China pushes industrial upgrading

Key decisions for the implementation of Made in China 2025 regarding smart manufacturing



Source: MERICS research

Forward-looking strategic planning

Long-term planning is a strong point of China's top-level design. Chinese leaders are appointed for two five-year terms and are less exposed to the pressures of public opinion than leaders in liberal democracies. This enables them, in times of smooth economic growth, to pay less attention to short-term pressures and concentrate on long-term goals. The long-term vision of Made in China 2025 for a "Manufacturing Superpower" allows the government to initiate today the necessary measures and work on the roadmap for industrial modernisation step by step.

Large state funding

Further advantages of Chinese industrial policy include large government funds and subsidies and the ability to channel them into priority areas. The recently established Advanced Manufacturing Fund (国家先进制造产业投资基金) is a 20 billion CNY (2.7 billion EUR) fund, although the exact funding period remains unclear.[14] In comparison, the German government has so far provided about 200 million EUR for research and innovation for Industry 4.0 technologies.[15]

Long-term planning is a strong point of China's top-level design.

In the same month that Made in China 2025 was released, the state-owned State Development and Investment Corporation set up a company with limited partnership to manage the Advanced Manufacturing Fund (the SDIC Advanced Manufacturing Investment Fund (Limited Partnership)) (国投先进制造产业投资基金（有限合伙）). The central government paid 6 billion CNY directly into the fund, while the state-owned State Development and Investment Corporation and the Industrial and Commercial Bank of China contributed 4 billion CNY and 5 billion CNY respectively. Some provinces also contribute to the Advanced Manufacturing fund. It has already started to make investments: for instance, purchasing shares in the battery and electric vehicle maker BYD worth 1.5 billion CNY and investing in a joint venture by several Shanghai robot makers.[16]

In addition, other government funds have also provided substantial sums for the development of smart manufacturing technologies. Among them are the National IC Fund (国家集成电路产业投资基金) and the Emerging Industries Investment Fund (国家新兴产业创业投资引导基金) with capital of 139 billion CNY (19 billion EUR) and 40 billion CNY (5.4 billion EUR) respectively at their disposal.

Policy innovation through experimentation

China has demonstrated through its industrial policy that it is very good at experimenting with new business models and new technologies. The central government often tests new approaches through pilot projects. These projects later serve as models for the nationwide roll-out of new technologies. In 2015 and 2016, the MIIT initiated more than 200 projects for smart manufacturing at enterprise level. In addition, the MIIT is establishing manufacturing innovation centres and pilot cities for Made in China 2025, such as the coastal city of Ningbo and several cities in the Pearl River Delta.[17] The demonstration projects focus, for example, on the implementation or integration of complex Enterprise Resource Planning (ERP), Manufacturing Execution Systems and Customer Relationship Management (CRM); on the use of RFID in components and material flows; the deep penetration of production with real-time monitoring; or cloud platforms for customer and supply chain management.

Rush of local governments to emerging industries

The rush of local administrations to support smart manufacturing accelerates and amplifies Made in China 2025: the central government campaign caused enthusiasm for smart manufacturing among local governments and greatly enhanced the impetus of previous local efforts. Local governments hasten to build China's new leading industrial basis for emerging technologies, which promises large economic benefits and support from the central government. In their pursuit to outperform their local rivals, local cadres mobilise massive financial resources and often exceed national targets by a considerable margin. Whereas the central government defines the policy priorities, it is the local governments that actually determine the pace and direction of smart manufacturing growth.

It is the local governments that determine the pace of smart manufacturing growth.

The intense push from local activities is especially visible in robotics. Local governments have opened or are planning to open nearly 40 parks for the development of the robotics industry (Figure 8). By October 2016, at least 70 provinces, cities and county-level administrations had released local Made in China 2025 strategies with specific local priorities. MERICS identified concrete robotics subsidy pledges in 21 cities and 5 provinces for promoting industrial robotics at a total value of nearly 40 billion CNY. These local subsidies will contribute more to the usage of industrial robots than central government spending because they are twice as large as the new national Advanced Manufacturing Fund.[18]

Figure 8

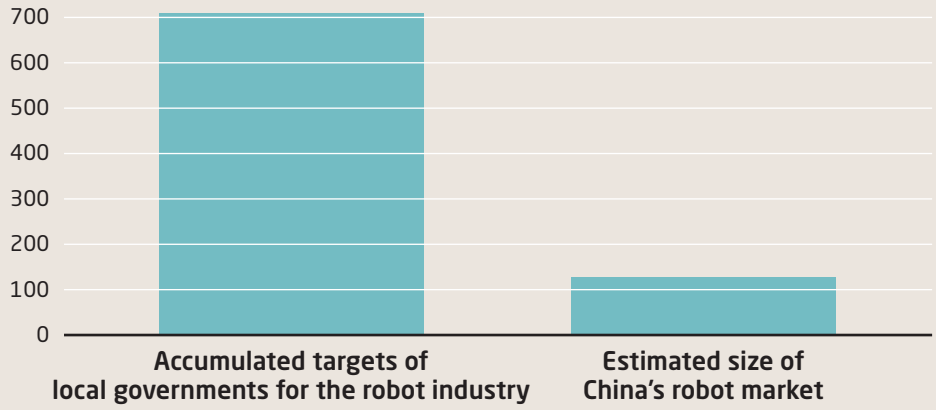
The "robot craze" of China's local governments

China's new local robot industrial parks risk to create overcapacities

Targets for industrial output of local robot hubs (in billion CNY) until 2020

More robots than needed

Local targets for robot industry exceeds actual demand (in billion CNY) until 2020



Source: MERICS research, MIIT

3.2 THE STRENGTHS COME WITH INHERENT WEAKNESSES

The forcefulness of the industrial policy campaign is impressive. However, the top-down approach comes at a cost because its strengths come with built-in weaknesses.

Catch-all approach misses specific enterprise demands

The enormous mobilisation capacity leads to an over-ambitious catch-all approach that does not meet the specific needs of enterprises. The campaign-style policy of Made in China 2025 disregards the role of a developed entrepreneurial environment and management practices in realising smart manufacturing. The government imposes the priority of smart manufacturing on enterprises without considering their actual circumstances. Many barely automated enterprises are unprepared for using advanced technologies. Focusing on the most advanced technologies while disregarding the need to upgrade to basic automation and digitisation technology will lead to disappointing or even harmful results. For example, enterprises with rather simple software systems and non-computerised automation can hardly be expected to deal with software integration and intelligent machines.

Blind spot: management and gradual change

China's industrial policy underestimates the role of enterprise organisation and gradual improvement of production processes as ways to realise smart manufacturing. The government tends to see industrial upgrading as a purely technical task of installing new equipment. The reason for this approach is simple: focusing on technology delivers fast, impressive and quantifiable results – such as rising demand for robots.

However, this fixation on hardware neglects the fact that progress in industrial production is to a large degree a matter of organising management and manufacturing processes. Key to industrial upgrading are the optimisation of industrial processes through continuous improvement (Kaizen), the implementation of lean management and the role of expert consultants.

Inefficient allocation of funds

Local governments risk duplicating projects, wasting money and outpacing demand.

The provision of massive funds is often associated with the misallocation of public money. In China it's often not the most promising and efficient enterprises but those with the best contacts in the political system that receive funding. Smart manufacturing is no exception. A Southern Chinese electronics firm, for example, secured funding for a pilot project because it hired a former MIIT official.[19] In the robotics industry there are also instances of rent-seeking on the part of enterprises and the misappropriation of funds earmarked for innovation.[20]

Duplication of effort by local governments

The enormous local enthusiasm for smart manufacturing also creates serious problems: Local government efforts are often uncoordinated and redundant; they risk duplicating projects, wasting money and outpacing demand. A run on a particular type of technology often leads to manufacturers producing only low-value solutions. The risks of a subsidy glut and overcapacities in smart manufacturing are highly imminent, similar to the existing problems in industries such as steel, coal and chemicals.

Other sectors such as the photovoltaic and the wind industry have also demonstrated that local subsidy gluts and tax reliefs for companies often lead to overinvestment. Overcapacities cause a massive decline in prices and shrinking margins. Given the artificial incentive structure of state subsidy regimes, Chinese enterprises normally do not react to increased competitive pressure with more innovative activity. Instead, many enterprises concentrate on mass producing low-tech products.

MIIT Vice-Minister Feng Fei said that "the biggest worry in the implementation process of Made in China 2025 is that there could be another round of duplicate construction".[21] China's robotics industry is heading for overcapacity because local subsidies are extremely high and support measures uncoordinated. At first, this will only affect the Chinese market, especially the low-end segment. If Chinese robot makers become more active globally, this could also lead to an export of overcapacities to global markets.

3.3 ECONOMIC CHALLENGES IMPAIR POLICY EFFECTIVENESS

Apart from policy weaknesses, there are several contextual economic barriers and pressures that have negative consequences for policy activities and incentive structures for enterprises.

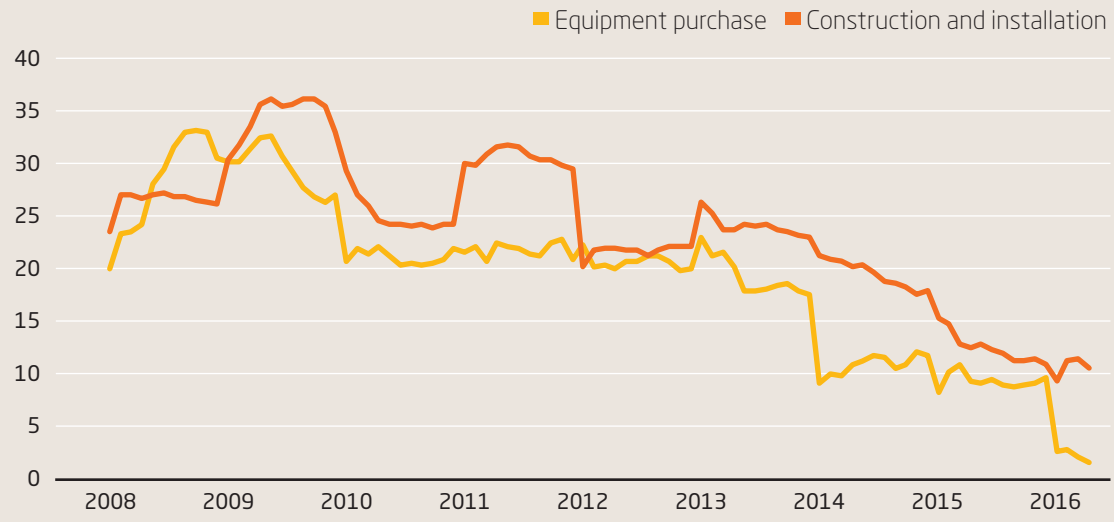
Economic slowdown affects willingness to invest

The current worsening of economic conditions will delay or hinder long-term planning for industrial upgrading. Due to the economic slowdown, the central government is likely to postpone the transition to an innovation economy as it responds to short-term economic challenges via traditional methods of crisis management such as increasing infrastructure investment. Corporate debt and overcapacities decrease the willingness of enterprises to invest in new and advanced machinery and information technology. The purchase of equipment in general has already slowed markedly in 2016 (Figure 9). Demand growth for industrial robots significantly dampened in 2016 as the automotive industry, the largest user of robots, faced stagnating car sales and cut back orders for new robot units.[22] As smart manufacturing increases productivity and capacities, upgrading might even increase overcapacities.

Figure 9

Chinese enterprises are less willing to purchase new equipment

Growth of fixed-asset investment in equipment and construction (year on year change, in per cent)



Source: National Bureau of Statistics

Lack of skilled workers

The lack of talent makes it very difficult for many Chinese enterprises to install and use smart manufacturing technologies. Complex IT processes and computerised machines, such as cross-industry technologies, require detailed expertise in various fields of automation, engineering and software. A shortage of skilled workers for smart manufacturing is an issue in many countries, but it is even more severe in China. Chinese enterprises perceive the skill shortage as one of the major problems for industrial upgrading for both simple automation and highly sophisticated IT-based processes.[23] China's education system and the Chinese universities struggle to provide sufficient numbers of skilled experts for sophisticated tasks in the high-tech industry. [24]

Impending lay-offs due to automation

The consequences of industrial upgrading for the labour market will further diminish the initial enthusiasm among political circles. The government is not well prepared for mass lay-offs due to industrial upgrading. Made in China 2025 has a clear blind spot here. The labour market is one of

the biggest worries to the central government. The 50 million new jobs the government plans to create in urban areas until 2020 might not be sufficient to absorb new waves of migrants into the cities. The manufacturing industry has reached its limits for providing jobs, but new drivers of growth in the service sector have not yet realised their potential as a job machine.[25] In the midst of an already tense employment situation, technological upgrading and further job losses will increase the danger of political instability and unrest. Large-scale dismissals, which are also (but not solely) related to automation, are already happening: Haier laid off 26,000 employees (18 per cent of its entire workforce) after it had heavily invested in digital factories.[26]

The government is not well prepared for mass lay-offs due to industrial upgrading.

The combination of inherent policy weaknesses and unfavourable overall economic conditions is likely to limit the effect of Made in China 2025. It remains to be seen if the decision makers are able to adapt their policy strategies to the challenges that lie ahead. As the next two chapters will show, it is exactly these policy strategies that will determine the success or failure of China's manufacturers and tech suppliers.

4. Manufacturers: a small but growing group of challengers to industrial countries

KEY FINDINGS

- Made in China 2025 will have different effects on different enterprises: China will have frontrunners, hopefuls and latecomers in the use of smart manufacturing.
- A small number of frontrunners will soon become highly competitive on the world market.
- The frontrunners upgrade their processes out of their interest, but policy is important in accelerating their efforts.
- The policy will have the biggest impact on the hopefuls. This group of enterprises operates at a less advanced level but will move to upgrade production to the next level if provided with the right incentives.
- The hopefuls' success or failure will depend on effective policy implementation.
- The development of the group of hopefuls will determine China's competitiveness in smart manufacturing in the medium term.

Even if Made in China 2025 will not fully accomplish its objective of achieving the widespread application of smart manufacturing in the next decade, the plan will develop an enormous impact that will be felt not only in China but throughout the global economy. Industrial countries should have no illusions: Made in China 2025 will elevate a small but powerful group of Chinese manufacturers, dramatically increasing their competitiveness.

The central issue is to what degree government policies will mobilise manufacturers to modernise their processes. The smart manufacturing boom that is beginning in China will be very unequally distributed among enterprises in China. This chapter differentiates between three distinct groups of Chinese manufacturers (Table 2).

Manufacturers use smart manufacturing to improve their production and management processes. Some of these companies are hybrids: they manufacture their own products and, in addition, supply smart manufacturing products and services to other enterprises.

The biggest and most immediate challenge to advanced economies and their manufacturers will come from a small group of frontrunners. The frontrunners are the few enterprises that are developing advanced manufacturing out of a strong business interest. They are in the best position to use the political support of Made in China 2025 to their advantage.

The latecomers, the largest group, will hardly gain anything from the policy campaign no matter how effectively it is implemented. They simply do not possess the technological prerequisites or the business incentives to expand into advanced manufacturing any time soon.

The hopefuls, the third group, are decisive for China's future competitiveness. The frontrunners are the challengers of today, the hopefuls could be the challengers of tomorrow. But they will need to be activated through policy. Their development is the most uncertain of the three groups and most strongly depends on the successful implementation of Made in China 2025.

Table 2

China's smart manufacturing develops at different speeds
Characteristics of frontrunners, hopefuls and latecomers

	Frontrunners	Hopefuls	Latecomers
Current level	Highly automated and digitised (Industry 3.0)	Progressing towards high automation and digitisation (from Industry 2.0 to Industry 3.0)	Manual labour and basic automation (Industry 1.0 and 2.0)
Importance of business interest for progress	High	Low, potentially increasing	Low
Importance of policy for progress	Medium	High	Low
Prospects for the next ten years	Enormous benefits from using advanced technology (Industry 4.0)	Potentially consolidating automation and digitisation (Industry 3.0) and testing out advanced technology (Industry 4.0)	Mainly remaining at the level of manual labour and basic automation

4.1 FRONTRUNNERS COMBINE BUSINESS INTEREST WITH POLICY SUPPORT

The frontrunners are a small group of China's most advanced users of smart manufacturing. They established very solid foundations using Computer Numerical Control (CNC) machines, ERP, MES, industrial robots and similar technologies. They are already running research, development and demonstration for the application of Industry 4.0 technology, for example RFID, wireless sensor networks and virtual reality. The frontrunners will soon close the gap to the most advanced international level of production technology in their respective industries.

The frontrunners can be found across industrial sectors. They include private as well as state-owned enterprises (Table 3). Similar to other countries, the automotive, electronics and metals industries have a high penetration of MES, ERP and industrial robots. For others, such as paper making and garment production, smart manufacturing is less prevalent. However, when compared to car production in industrial countries or by OEMs in China, the production of Chinese carmakers is very backward. In contrast, industries such as electronics have achieved an internationally quite advanced level.

Examples of frontrunners include manufacturers of consumer electronics and home appliances such as Haier and Hisense, and increasingly Midea and Gree. The construction machine manufacturers Sany and Zoomlion also have advanced production processes. The automotive and steel industries are relatively backward compared to foreign factories. However, the carmaker SAIC, car component supplier Weichai and steelmaker Baosteel are rising as active users of cutting-edge technology.

Business initiative is key to industrial upgrading

Key to the success of the frontrunners is their enterprise-led initiative. This differs from most other Chinese enterprises. The frontrunners upgraded to advanced manufacturing to increase profitability, ahead of government incentive programmes. Sany, for instance, began its "Digital Factory" programme in 2009.

Many frontrunners are deeply integrated in world markets and are exposed to real and open competition. This creates powerful incentives to increase productivity through the use of smart manufacturing. The frontrunners understand new production technology as fundamental to expanding or consolidating international market activities and shares. Their managers are convinced that success in overseas markets, as suppliers or OEMs, is only possible if they can achieve a high level of productivity, quality and customisation, and if they are able to project the image of a modern enterprise.

The central government now sees them as successful models and provides financial support. The frontrunners could succeed without policy support, but Made in China 2025 is an important catalyst for their progress. All frontrunners have been awarded national pilot projects for smart manufacturing.

Smart manufacturing boosts international presence

The upgrading efforts enormously increase the production capabilities of the frontrunners. Smart manufacturing enables them to make higher quality products more quickly, cheaply and flexibly. Within China, the frontrunners are the only enterprises that are in a position to reap immediate benefits from the use of Industry 4.0. For instance, 15 particularly successful national pilot projects reduced operative costs by 20 per cent and the product development cycle by more than 30 per cent, according to an MIIT survey. The projects were able to increase productivity by nearly 30 per cent and decrease the amount of deficient products by 20 per cent.[27]

The benefits of smart manufacturing strengthen the frontrunners' international presence.

These benefits of smart manufacturing strengthen the frontrunners' international presence. For example, Haier more than doubled its operational revenue on non-Chinese markets from about 8 billion CNY to more than 18 billion CNY between 2012 and 2015, after it released its "internet factory" programme in 2012.[28] Smart manufacturing is a necessary but insufficient condition for reaching a significant global presence. Product innovation and branding are equally important. Haier performed well in these categories. Several frontrunners, on the other hand, will have difficulties globally in spite of modern production methods, as their design and marketing capacities lag behind.

Policy weaknesses will not affect the frontrunners

The frontrunners will be the least affected by the weaknesses of the political strategy. The high ambitions of the campaign match their advanced status. Since they have a strong business case for smart manufacturing they are less likely to be affected by the pitfalls of Made in China 2025 discussed in Chapter 3. They are also in a better postition to overcome skill shortages by establishing internal research and training centres and making use of external consulting. While inefficient policy will have less impact on the frontrunners, these companies are still vulnerable to the consequences of an economic downturn. Corporate losses and overcapacities could delay their investment in equipment and slow down their business in the short term. However, economic turbulence could also provide an opportunity for the frontrunners as their modernised production lines would give them an edge over their domestic rivals..

Table 3

Leaders in smart manufacturing
Examples and effects of industrial upgrading in frontrunner enterprises

Haier	Sany
Industry: Electronics 2.7 % of revenue spent on R&D 21 % of revenue earned abroad	**Industry:** Machinery 5.1 % of revenue spent on R&D 44 % of revenue earned abroad
Smart factories in • Shenyang (refrigerators) • Foshan (washing machines) • Zhengzhou (air conditioners) • Qingdao (water heaters)	**Smart factories in** • Changsha Ningxiang (mobile cranes) • Changsha No. 18 (trucks) • Beijing (pile drivers) • Shanghai Lingang (excavators)
Key Projects 2012: "Internet factory" strategy • Platform for product customisation and supply chain management • Research centre for smart manufacturing • Participation in national pilot projects	**Key Projects** 2007: First investment in robots 2009: "Digital factory" project • Acquired German machine maker Putzmeister • Platform for smart services of construction machines • Participation in national pilot projects
Effects Result of upgrading at Shenyang refrigerator factory: • Order-delivery time down from fifteen to seven days • Productivity doubled	**Effects** Results of upgrading at Changsha truck factory: • Productivity +24% • Material storage -30%

Weichai	Shanghai Electric
Industry: Automotive 4.4 % of revenue spent on R&D 55 % of revenue earned abroad	**Industry:** Energy Equipment 3.2 % of revenue spent on R&D 11 % of revenue earned abroad
Smart factory in • Weifang (No. 1)	**Smart factory in** • Shanghai Highly Lingang (compressors for air conditioners)
Key Projects • Acquired 70 % share of German hydraulics firm Linde Hydraulics (former Kion) • Smart manufacturing project with China Telecom • Participation in national pilot projects	**Key Projects** 2007: First investment in robots • Acquired two German automation firms • Participation in national pilot projects
	Effects Result of upgrading at Shanghai compressor factory: • Robot density of 461 per 10,000 employees in a labour-intensive industry • Production per employee rose from 295 to 1131 compressors

Source: Based on enterprise publications

4.2 HOPEFULS: WINNING OR LOSING?

The hopefuls play a decisive role for China's international competitiveness. Effective industrial policy is most critical for this group. If the policy succeeds, it will enable these companies to challenge the global market position of multinational corporations in the medium term. If many of the Chinese hopefuls effectively use smart manufacturing to expand internationally, China's economic strength will grow quickly. A large proportion of the hopefuls are not yet influential on international markets and their rise might surprise established market players.

As of today, the hopefuls are not yet close to achieving the most advanced level of production. For the most part, this relatively large group is in the midst of upgrading from basic automation and electrification (Industry 2.0) to numerical control and software-based production (Industry 3.0). The greater the effectiveness of Made in China 2025, the bigger the group of hopefuls to effectively use Industry 4.0 in the medium term.

The hopefuls are a large heterogeneous group, including large state-owned and private enterprises as well as many small and medium enterprises. Examples for hopefuls are the state-owned aircraft and defence corporation Aviation Industry Corporation of China (AVIC), as well as the TV maker Changchong, energy equipment producers such as Shaangu and the ship maker Nantong COSCO KHI Ship Engineering. Many hopefuls take part in the pilot projects launched by the MIIT and local governments (Table 4).

Table 4

Political support for hopefuls

Select national demonstration projects for the application of smart manufacturing supported by the MIIT in 2015

Aviation
AVIC (Changhe)
AVIC (Liyuan)
AVIC (Xi'an Aircraft Industry)
CASIC

Automotive
Chang'an

Chemistry and Petroleum
Sailun
Sinopec

Clothing
Meike
Redcollar

Energy Equipment
Shaangu
TBEA

Metals and Materials
Angang
China United Cement Corporation
Chinalco
Janus Precision Components
Jinjiang
Kocel
Sinoma (Taishan Fiberglass)

Electronics
Changhong (Hefei)
Changhong (Sichuan)
Shenzhen Rapoo
Skyworth
Yangtze Optical Fibre and Cable

Food, Beverage and Medicine
Kanion
Polypharm
Shandong Companion
Sinofert
Yili

Shipbuilding
Nantong COSCO KHI Ship Engineering

Source: MIIT 2015

Policy is the main trigger of industrial upgrading

Unlike the frontrunners, the hopefuls rely on the top-down approach of Made in China 2025. For them the policy campaign is the main driver for their upgrading activities towards smart manufacturing. Their business interest is currently too weak to lead to comprehensive investment in cutting-edge automation and digitisation technology without policy support. But the national pilot projects are an important trigger and provide substantial support for testing advanced technology and improving efficiency. Senior managers of large state-owned enterprises respond

particularly well to the policy priorities of Made in China 2025 in order to meet political targets and advance their own careers. The big push towards smart manufacturing is especially visible in the aviation industry (Table 5). State-owned aircraft makers have considerably increased their activities in this area in 2015 and 2016. AVIC, for instance, developed a comprehensive plan for smart manufacturing parallel to the release of Made in China 2025. The company started as many as four pilot projects under the national programme including one in the city of Xi'an.

Table 5

Still a long way to go for Industry 3.0 and Industry 4.0

Qualitative assessment of the development status of industrial production in the Chinese aircraft manufacturing industry based on study by AVIC engineers

Industrial paradigms	Technologies and methods	Level of implementation in production
Industry 2.0	**Electrification and professionalism** • Use of electric devices • Division of labour	Very High
Industry 3.0	**Automation** • Processing and assembly • Data collection • Logistics	High
	Lean management • Industrial processes • Just-in-time production • Value analysis • Six sigma	Medium
	Flexibility • Production modules • Production lines • Costumer orientation • Organisation and management	Medium
Industry 4.0	**Digitisation** • Production • Product real-time monitoring • Integration/interoperability of virtual and physical data	Medium
	Networking • Enterprise management • Design processes • Manufacturing • Logistics • Product services	Low
	Smart application • Products • Businesses • Design decisions • Manufacturing decisions • Production modules • Production system	Low

Source: AVIC, MERICS

Success depends on efficient policy implementation

For the hopefuls, the success or failure of the policy initiative will have the biggest impact. These companies are at a decisive point in time: Good policy implementation can turn them into front-runners of smart manufacturing in the medium term. But bad policy implementation may lead them down the wrong path and eventually discourage them from using smart manufacturing technology effectively. As local governments mobilise the most funding, the effectiveness of various local policies will play a critical role. Local governments in wealthy coastal areas are especially vehement promoters: coastal provinces in the east and the south use about half of all the industrial robots in China.[29] Guangdong alone now accounts for 15 per cent of China's installed robot stock.[30]

The long-term challenge for policy makers is not only to provide incentives to the hopefuls to modernise their production processes but also to make them understand that upgrading their facilities is in their own best interest. Industrial policy can help these enterprises to get out of the starting blocks but eventually the firms have to discover for themselves that investing in modern facilities can increase productivity and reduce costs. For instance, a supplier might realise that investment in automation technology helps to fulfill quality requirements set by international OEMs. The high quality standards set by international smartphone companies are a case in point: They have already led to a highly automated supply chain for smartphone parts in China.

Policy weaknesses create many pitfalls

Identifying such business interests will be especially difficult for state-owned enterprises. The ambitions of Made in China 2025 to rapidly reach the most advanced level of production technology run the risk of leading to projects that look impressive but fail to address the challenges faced by companies that lack the necessary prerequisites. For instance, Changhe, a subsidiary of AVIC, has built a futuristic factory that is too advanced to match the current level of the company's production technology. Sany CEO Tan Xiuguo once said, "even if they [the Europeans] sell us their technology, it is not for granted that Chinese enterprises can actually use them".[31]

If the strategy's weaknesses are not addressed, many hopefuls will not see the policy's benefits: should their pilot projects run into difficulties, these companies lose their willingness to invest in modern production lines without further government support. The top-down approach can thus deter companies from upgrading to smart manufacturing technologies. For example, some enterprises have already de-installed industrial robots when it turned out that the new equipment was either too costly or too complicated for them to operate. Similarly, introducing new industrial software is a lengthy, time-consuming process that requires intensive training of employees.[32]

As local governments mobilise the most funding, the effectiveness of various local policies will play a critical role.

4.3 LATECOMERS: LOSING OUT IN THE YEARS AHEAD

The latecomers have made the least progress in upgrading, having installed only basic electrified and automated devices at most. This is the largest part of Chinese industry, including especially small and medium private enterprises, but also larger private and many state-owned companies. They will not make significant progress towards smart manufacturing in the next five years.

The latecomers lack the incentives to upgrade industrial production. The employment of cheap labour and the massive production of low-cost products still serves as a successful business model. However, even as the pressure to automate and digitise production increases, there are several barriers to upgrading.

The old generation of management, which has been in place since the 1980s, pays little attention to the quality of equipment and is not convinced of the benefits of upgrading. Limited funds and low profit margins make the latecomers very reluctant to spend money on equipment that does not guarantee a return on investment within one or two years. Instead of investing in their own facilities, many entrepreneurs prefer to invest in the booming real estate market as this promises higher profits.

In contrast to the hopefuls, the latecomers do not feel encouraged by China's industrial policy to upgrade to smart manufacturing technologies. While Made in China 2025 has set in motion

extensive funding efforts, the programme fails to reach a large part of Chinese industry: most latecomers receive only marginal support or none at all.

In the years to come, these companies are likely to experience diminishing influence on domestic and international markets. They cannot compete with enterprises from industrial countries. As soon as wages rise substantially in China, they will also become weaker in comparison to enterprises in developing countries. Many of them will survive by continuing to focus on low value and low quality products, which are still in high demand in China. Other industrial areas that require no or limited automation will also continue as before – the decision not to upgrade to smart manufacturing will not have any negative consequences for these companies.

China's industry will develop at different speeds.

China's industry will develop at different speeds: on the one hand, there are the latecomers that are trailing behind in industrial modernisation, on the other hand there is the small but growing number of frontrunners and successful hopefuls. This second group of manufacturers will come to the fore, compete in international high-tech markets and change the structure of these markets. Meanwhile, the Chinese government hopes that it can create a similar trajectory for suppliers of smart manufacturing technology – as the next chapter will show.

5. Chinese tech suppliers: lagging behind but rising

KEY FINDINGS

- Several Chinese tech suppliers will be propelled forward by China's smart manufacturing initiative. They will bridge the technology gap and become serious domestic and international competitors in fields such as robotics, industrial software and 3D printing.
- The pace and degree to which Chinese tech suppliers will become competitive depends largely on the effectiveness of the initiated policy activities.
- A significant technology gap still exists. Accordingly, foreign suppliers currently greatly benefit from China's smart manufacturing boom. However, they need to be prepared to see their market opportunities and shares dwindle swiftly within the next ten years.
- The pace of technological catch-up and intensifying competition varies markedly by technology. The competitiveness of Chinese companies will develop more rapidly in some areas than in others.
- The Chinese ambitions will lead to an increase of technology-seeking FDI and knowledge acquisitions. Chinese enterprises, spurred by political targets, support and incentives, will seek to accelerate their technological catch-up through strategic technology investments abroad.

International suppliers of smart manufacturing technologies are currently in a gold-rush mood in China. China's industry has a huge demand for high-end machine tools, smart sensors and other technology. However, the less-advanced Chinese suppliers are unable to provide the technologies for this sudden boom in a short time. For the time being, China depends on foreign supply to push its smart manufacturing revolution forward.

Tech suppliers are enterprises that provide technologies and services necessary for realising automation, digitisation and smart manufacturing. These technologies include, for instance, CNC machines, industrial software, (smart) sensors, industrial robots and RFID. The Chinese definition of smart manufacturing also encompasses 3D printing and industrial e-commerce.

China depends on foreign supply to push its smart manufacturing revolution forward.

Yet some of the Chinese tech suppliers are already well out of the starting blocks. They will become competitive in individual segments of the Chinese market much faster than the status quo would suggest. Subsequently, the gold rush for foreign suppliers will end sooner than expected. Three pertinent case studies at the end of this chapter will illustrate these insights with regard to industrial robots, 3D printing and industrial software.

5.1 STATUS-QUO: DEPENDENCE ON FOREIGN TECHNOLOGY

Chinese tech suppliers for manufacturing are basically well suited for the Chinese market: their focuses and strengths are low-tech and low-price products. The functionality of Chinese industrial software is, for instance, not as broad or complex as comparable foreign software solutions. This fits well with the needs of Chinese small and medium enterprises, who cannot afford the expensive international products and are satisfied with simple software. Furthermore, Chinese tech suppliers have an in-depth understanding of the specific needs of Chinese consumers and develop solutions adapted specifically for the Chinese market.

However, China's suppliers do not possess the technological abilities to realise the ambitions of Made in China 2025 to catapult industry into the age of smart manufacturing in very

short time. China has no choice but to rely on foreign technology to upgrade its industry. The technological gap between foreign and Chinese suppliers is vast. In many cases, there is no serious Chinese alternative to foreign advanced production technology in high-end sectors. Even if Chinese enterprises do offer products in these sectors, they have to rely largely on foreign core components. The market shares of Chinese suppliers of smart manufacturing technologies are at a low level (see case studies below).

5.2 POLITICAL GOALS AND INSTRUMENTS: MAKING CHINESE TECH SUPPLIERS DOMINANT IN CHINA

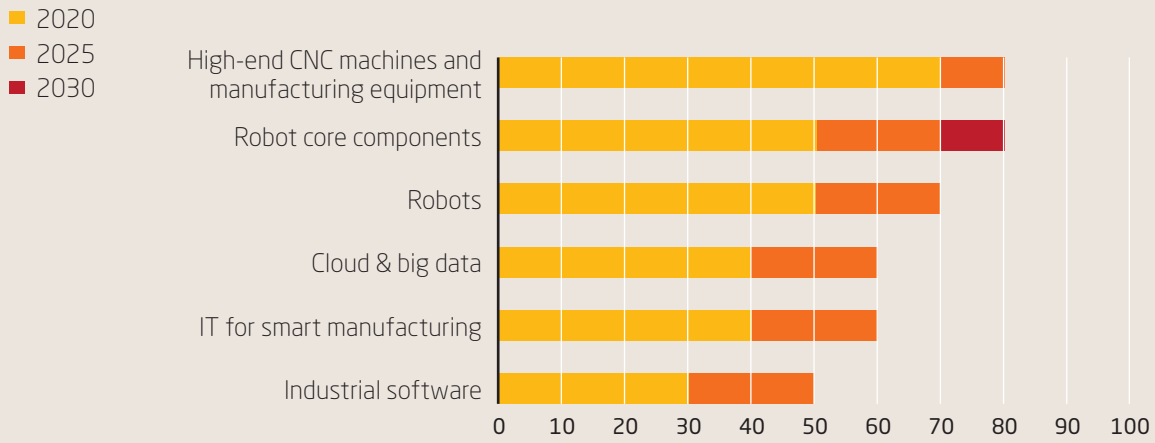
The Chinese government aims to close the technology gap between Chinese and foreign suppliers and to substitute foreign with Chinese technology by 2025. The government puts all necessary political and financial resources into making Chinese tech suppliers dominant in politically selected industries like robots and high-end machine tools. The envisioned market shares for Chinese products and brands in the "Made in China 2025 Key Area Technology Roadmap" demonstrate the ambitious political goal of reducing the market share of international technology suppliers (Figure 10).

The implementation of Made in China 2025 will largely determine the pace and degree to which Chinese tech suppliers can become competitive. The same logic applies to manufacturers using smart manufacturing technologies in China. Over the coming years until 2025, China's policy makers will increasingly intervene in the market to achieve these goals. The Chinese government will use the whole array of innovation and industrial policy instruments mentioned in chapter 3 to enhance the competitiveness of Chinese suppliers in politically selected industries.

Figure 10

Made in China 2025: replacing foreign smart manufacturing technology

Goals for the domestic market share of various Chinese smart manufacturing products (in per cent)



Source: Expert Commission for the Construction of a Manufacturing Superpower

R&D funding

The Chinese leadership channels substantial funds into the research and development of smart manufacturing.[33] The state research and development (R&D) activities focus especially on immature technologies that still await large-scale commercialisation. For instance, between 2014 and 2016, the Ministry of Science and Technology (MoST) launched 51 basic and applied science projects for 3D printing, 41 for cloud computing and big data, 5 for sensors and 16 for robotics. Because of the special importance of robotics, the Chinese government also uses industrial policy instruments such as subsidies to robot makers and buyers to promote technological development.

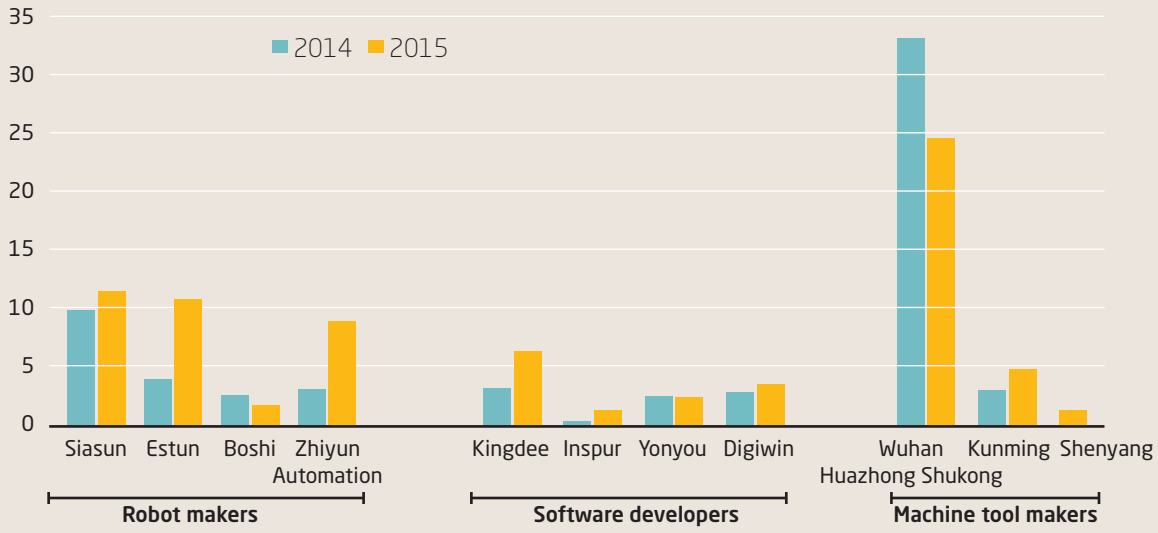
Capital injections for Chinese companies

The national and local governments nurture tech suppliers with generous state support. This includes, for instance, tax rebates for high-tech enterprises and for software developers.[34] There are also huge direct capital injections from government funds and innovation parks. The reported subsidies to tech suppliers can make up a significant share of their operational revenue: 1 to 6 per cent for some software developers (Figure 11). Measured in relation to their revenue, the subsidies for many tech suppliers have increased in recent years.

Figure 11

China's tech suppliers receive generous subsidies

Size of reported government subsidies as percentage of total operational revenue in selected enterprises for robotics, industrial software and digitised machine tools



Source: MERICS calculation based on various enterprise reports

The considerable government aid is intended to build a strong Chinese smart manufacturing industry. This creates fast developing, dynamic markets with many new players. However, the generous subsidies and corresponding market distortions are also likely to create significant problems for the development of tech suppliers. As demonstrated in chapter 3, the campaign-style policy and massive central and local government funding run the risk of causing misallocation, overcapacities and a supply surplus.

Discrimination against foreign enterprises

Industrial policy in China often entails measures to discriminate against foreign enterprises. The national and local governments restrict access to public procurement and limit the possibility of inbound foreign-direct investment. For instance, the official classification of "secure and controllable" ICT products keeps foreign products out of many areas. These measures are not yet as pronounced in smart manufacturing as Chinese tech suppliers are still too backward to benefit from national protectionism. However, it is very likely that the Chinese government will intensify measures to protect Chinese suppliers from foreign competition in these technology areas as soon as Chinese enterprises have a real chance to challenge the market dominance of foreign tech suppliers (see chapter 6).

5.3 FAST TECHNOLOGICAL CATCH-UP

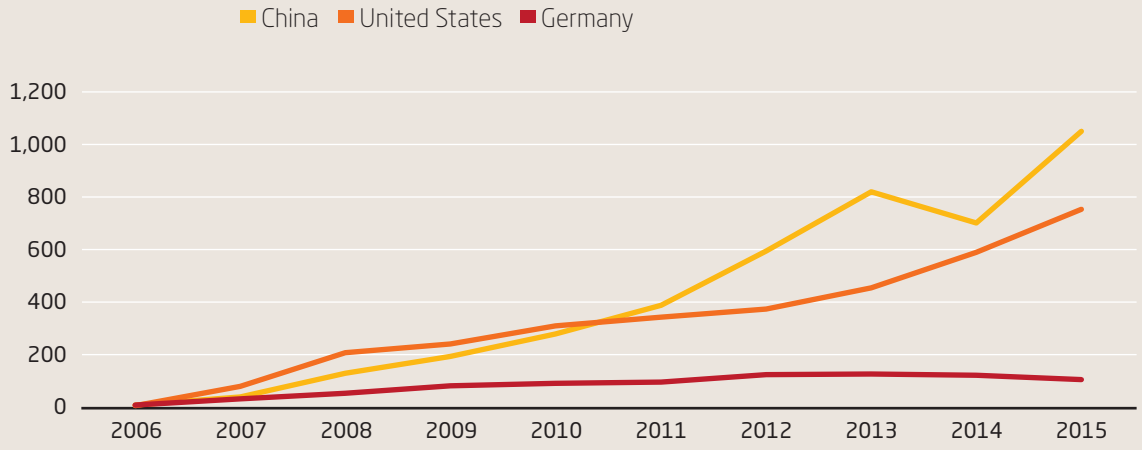
Government support through Made in China 2025 and previous policy initiatives has delivered the first visible results. Patenting activity (including patents, industrial designs and utility models) shows that China will contribute important innovations in the most advanced technologies for smart manufacturing in the coming years. The number of Chinese patents for Industry 4.0 related technologies has grown very rapidly since 2006 (Figure 12). Patent applications in China surpassed those in the U.S. in 2011.

Chinese innovation activities are particularly strong in technology fields with high political support: traditional industrial robots, wireless sensor networks and smart sensors. In contrast, Chinese innovation activities are weaker in cloud computing and big data, advanced robots and information security (Figure 13).

Figure 12

Increasing innovation in Industry 4.0 in China

Patent families (priority applications) for Industry 4.0 technologies at national patent offices (2006-2016)

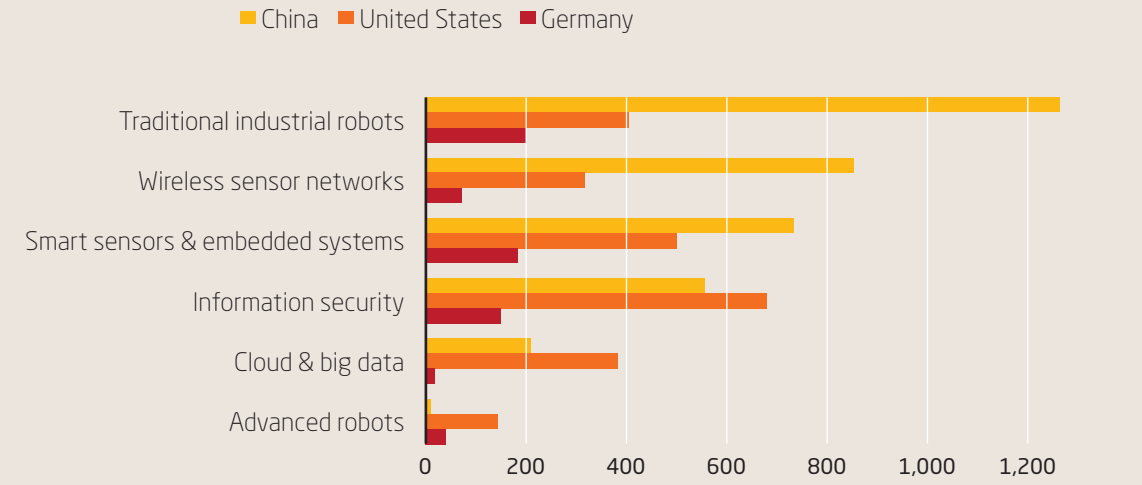


Source: Fraunhofer IAO[35]

Figure 13

China's innovation in Industry 4.0 focuses on robots, industrial communication and sensors

National patent families (priority applications) by technology (process and use patents not included)



Source: Fraunhofer IAO

The area in which China has the largest innovation potential is the development of use cases for smart manufacturing. Chinese enterprises are very creative about identifying business cases and deploying new technological innovations. The patent data clearly reflects this ability: patent applications for use cases account for nearly half of Chinese patent applications, compared to only roughly 20 per cent in the United States and Germany.

Chinese patent data for Industry 4.0 seems impressive. However, the number of applications allows only limited conclusions about the innovativeness. In general there is a huge number of low-quality patent publications in China, partly due to a dysfunctional government policy that rewards the registration of patents regardless of their quality. In addition, many patent applications for Industry 4.0 components in China seem to be lower quality than those in the United States or Germany, and their acceptance rate is also significantly lower.

5.4 STRONG INCREASE IN INTERNATIONAL TECHNOLOGY ACQUISITION NECESSARY

The innovation capacities of Chinese tech suppliers will increase in the coming years. However, Chinese enterprises and the government see the technology transfer from abroad as an important way to accelerate technological progress and to achieve the ambitious political goals. The need for the acquisition of foreign knowledge will presumably be most apparent where the gap between political ambition and domestic technological ability is the widest. In these areas enterprises will receive political support for acquisitions overseas. Robots, robot core components, semiconductors and high-end machine tools will be the foci of international know-how accumulation by Chinese companies until 2025.

There are many mechanisms and processes facilitating technology transfer. These include, for instance, technology spill-overs from inward-directed investments into China by foreign companies, cooperation with foreign companies and recruitment of foreign R&D personnel. A trend that is increasingly emerging is technology-seeking outbound investment into industrial countries by Chinese investors. The construction of R&D centres in industrial countries and the acquisition of foreign technology leaders can lead to absorption of essential knowledge and technology from abroad. Chinese investments in Europe's high-tech industries and the smart manufacturing industry have grown rapidly in recent years (see chapter 6).[36]

China sees the technology transfer from abroad as an important way to accelerate technological progress.

5.5 CONCLUSION

The case studies of China's smart manufacturing industry (see below) illustrate that Chinese suppliers are still significantly less advanced (Table 6). However, a number of Chinese enterprises will become serious competitors in technologies such as industrial software, robotics and 3D printing. The formidable market position of foreign enterprises in China will gradually diminish in the next ten years. Chinese production technology will eventually replace foreign technology.

The pace and extent of change will be decided by the effectiveness of policy measures, but also by the specific characteristics of the various technologies. The case studies below show, for example, that Chinese enterprises in 3D printing will catch up much faster than in robotics. In spite of the technology gap, however, Chinese robotics firms will become competitive faster than Chinese industrial software developers. This is due to the high cost of switching from existing foreign software systems, which are deeply integrated with the enterprises' processes, to new Chinese software.

Table 6

Technology catch-up varies between technologies

Characteristics of technology gap and development for industrial robotics, industrial software and 3D printing

	Industrial robots	Industrial software	3D printing
Technological maturity	High	High	Low
Technology gap	High	High	Medium
Foreign market dominance	High	High	Medium
Policy support	Very High	High	Medium
Prospects for catch-up	Medium	Low	High
Scope of international technology acquisition	High	Medium	Medium

Case Studies

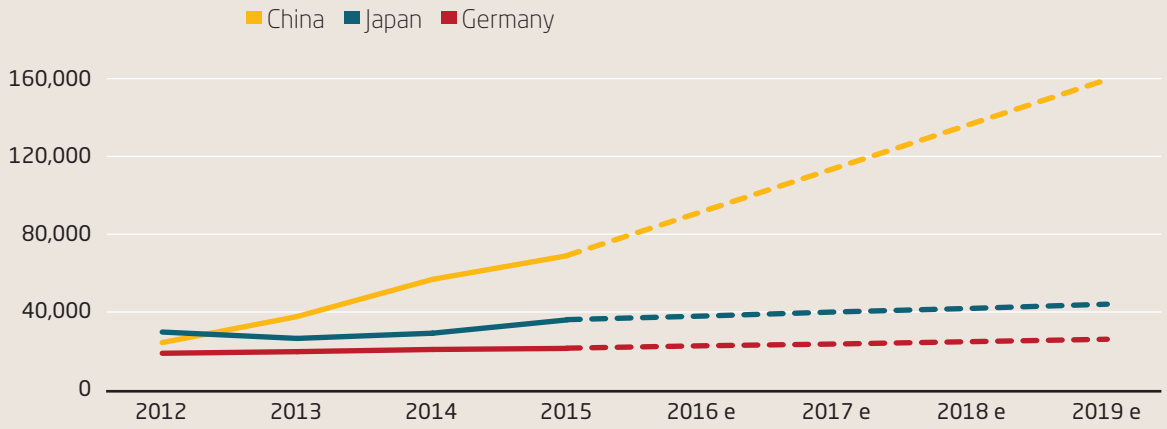
CASE STUDY 1: INDUSTRIAL ROBOTS

Political support and public focus on robotics are stronger than for any other manufacturing technology. The enthusiasm for smart manufacturing is particularly well reflected in the rapid market growth for industrial robots: with 66,000 shipped robots in 2015, China is the biggest robot market worldwide. Demand could reach 160,000 units by 2019 (Figure 14).

Figure 14

China is the largest robot market

Shipments of multipurpose industrial robots in select countries (in units)



Source: IFR, (from 2016 onwards estimates only)

Market shares and technology gap

The technological abilities of Chinese robot makers lag far behind those of leading foreign enterprises. Chinese suppliers cannot provide competitive high-performance robots such as six-axis and welding robots. To make things worse, the robots that Chinese enterprises can produce greatly depend on critical core components from abroad like gear reducers, servo motors and controllers (Figure 15). These account for more than 70 per cent of the production price of an industrial robot. In the most sophisticated area of robotics, in programming, Chinese enterprises have developed only very basic skills. The market structure clearly shows the technology gap: ABB, Fanuc, Kuka and Yaskawa visibly control the market, with a market share of roughly 70 per cent. For high-performance robots, the market share of international brands is as high as 90 per cent.

Chinese strengths

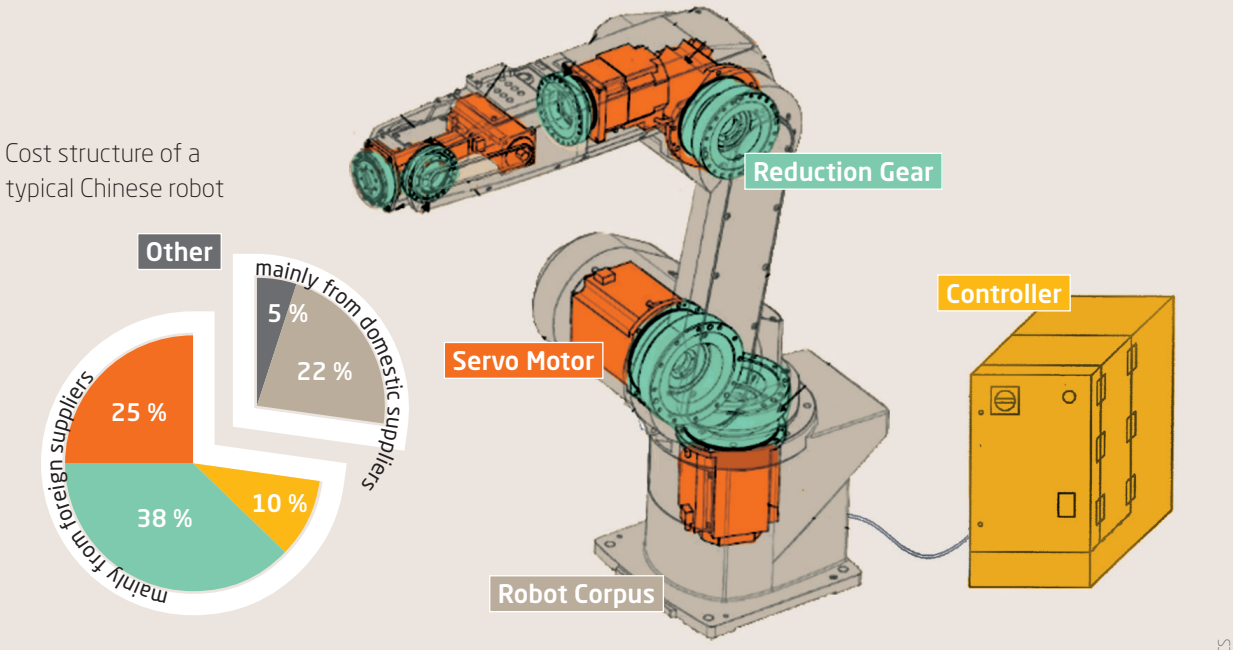
Chinese robotic manufacturers have been able to develop basic technological skills. Among the leading enterprises are Siasun, Guangzhou Shukong, Harbin Boshi, Estun and Effort. However, the technological catch-up process has so far only focused on the low-end sector, such as loading robots and adapting foreign robots to Chinese customers' needs. Due to the progress in these areas, Chinese robot manufacturers raised their market share from less than 5 per cent in 2010 to about 30 per cent in 2015.

Political support

The central government shows extraordinarily high ambitions for the development of the Chinese robotics industry: Chinese robot makers are supposed to reach a domestic market share of 80 per cent by 2025, according to the "Made in China 2025 Key Area Technology Roadmap". For sophisticated core components, the target is 70 per cent by 2025.

Figure 15

Chinese robot manufacturers depend on foreign suppliers for key components
Cost structure and sources for essential parts



Source: MERICS, Gongkong

To realise these ambitions, the government will again intensify its political incentives and funding mechanisms in the robot industry in the years to come. As chapter 3 has shown, central and local governments boosted their financial support to the robotics industry and users of robots. Without government support, Estun, for instance, would have incurred losses in 2015.[37] Many local governments support the purchase of robots with subsidies of between 15 and 30 per cent of the sale price.[38] In some cases, combined subsidies for producers and users add up to 100 per cent of the price.[39]

The huge political support could also backfire. There is a high danger of subsidy glut and overcapacities, especially in robotics. China will have a robotics industry valued at 716 billion CNY by 2020 or perhaps even earlier if all local targets for robot manufacturing industries are achieved.[40] In contrast, the MIIT estimates that the market size may only reach 100 billion CNY for industrial robots and 30 billion CNY for service robots by 2020. Other experts predict a market size of 200 billion by 2020. By 2025, it may reach 600 billion according to the China Robotic Industry Alliance.[41]

The state's subsidy glut has led to a tremendous increase in the number of Chinese robot companies. More than 800 Chinese robot companies are registered in China, approximately half of them in 2015. The majority of these companies have not yet reached the stage of mass production. Many of them just serve as rent-seeking vehicles to receive government subsidies and do not make any profit.

International cooperation

Even with massive state investment, Chinese robot manufacturers will have difficulty catching up in the next decade. To take a shortcut in technological progress, Chinese robot makers acquire foreign knowledge and technology. This is more apparent in robotics than in other smart manufacturing technologies. Foreign direct investment by Chinese flagship companies is rising fast. Midea's acquisition of the German robot company Kuka is only the most prominent case. In another example, the Chinese robot company Wanfeng bought the United States robotics firm Paslin

in April 2016. Already in early 2015, Effort acquired the Italian robot company CMA Robotics and opened an R&D centre in Italy. China's market leader Siasun acquired a vocational training centre in eastern Germany.

Outlook

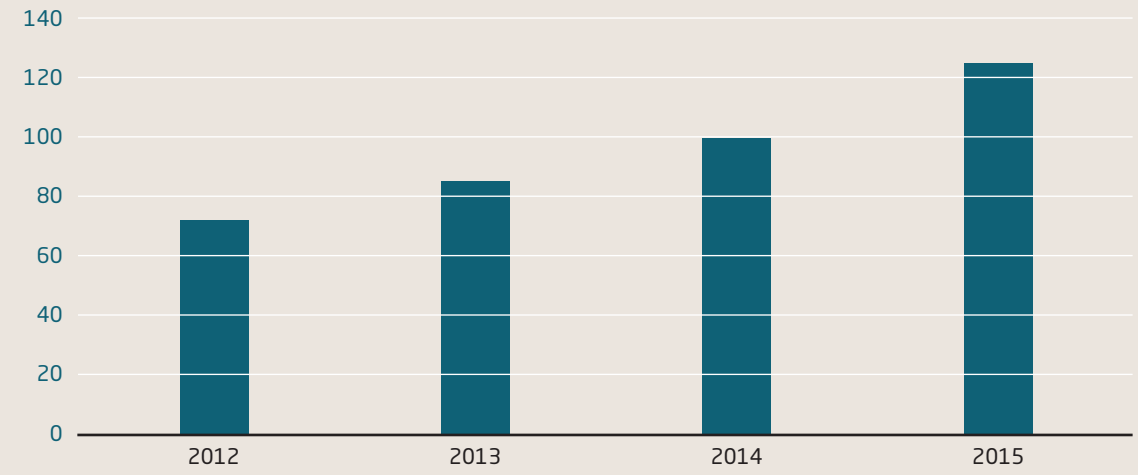
The success of foreign robot manufacturers in China will be significantly diminished by 2025. A number of China's leading robot makers will be ready to seize foreigners' market shares: the combination of political support and foreign knowledge acquisition will enable them to provide cutting-edge technology. The dominance of Chinese enterprises will at first become more and more evident in the lower and middle sectors of the market. With a certain time lag, Chinese enterprises will also increasingly manage to provide sophisticated six-axis robots, welding robots and core components. An area in which foreign robot makers could maintain a considerable advantage is intelligent robots for machine-human interaction. Chinese robot makers will rapidly catch up in robotic hardware, but will have more difficulties in robot programming. The rapidly growing market raises hope for foreigners that the number of units sold will remain high even if their market share drops.

CASE STUDY 2: INDUSTRIAL SOFTWARE, CLOUD COMPUTING AND BIG DATA

The growth rate of China's industrial software market in the last five years has been 17.5 per cent, well above the world average of 5.5 per cent (Figure 16).[42] This growth concentrates mainly on basic digitisation such as the installation of ERP and MES systems (Industry 3.0). While China is still catching up with Industry 3.0, industrial software solutions that integrate cloud and big data services are gaining in importance on the Chinese market.

Figure 16

Huge demand for industrial software
Industrial software market development in China (in billion CNY)



Source: CCID

Market shares and technology gap

Similar to industrial robotics, Chinese industrial software is also much less sophisticated than the products of SAP, Oracle and other foreign developers. Especially when it comes to complex software platforms for large corporations with international activities, the foreign products are unrivaled. This is obvious with regard to advanced IT solutions such as integrated cloud services and big data analysis. Consequently, the high-end segment of the industrial software market is dominated by international software providers. The top foreign developers account for more than 60 per cent of the generated value in the ERP market.

Chinese strengths

The ERP and MES products of Chinese software developers like Yonyou, Kingdee and Digiwin have made significant progress in terms of functionality and sophistication in recent years. The advantage of their software is that it is cheap and rather easy to use. A Chinese ERP software solution costs only a fraction of the price of an SAP ERP product.[43] This fits quite well with the needs of private small and medium enterprises, but also with state-owned companies. With a good understanding of the specific needs and user-interface preferences of Chinese users, they can deliver tailored products to Chinese SMEs. Chinese enterprises also begin to focus their strategies on new, integrated software solutions and try to develop Industry 4.0 products that cater to the needs of Chinese companies.[44] Leading internet enterprises like Alibaba and Tencent also increasingly offer industrial applications, especially in e-commerce and cloud computing.[45]

Political support

As in robotics, Made in China 2025-related documents seek to increase the share of Chinese software in the domestic market. However, political support for China's industrial software is less

visible than for robotics. The instruments are similar but have a lower scale than in robotics. These include tax relief, direct subsidies and incentives for local software parks.[46]

The government has not yet implemented extensive measures specifically aimed at limiting market access for foreign industrial software, although there are some restrictions for cloud computing and encryption software that can also affect the application of industrial software. So far, the government has deployed only a "soft" approach to technology nationalism. In 2016, the MIIT headed a series of events for Chinese software user and supplier companies to strengthen their exchange and to accelerate the application of home-grown software solutions in Chinese companies.[47]

However, the Chinese government will increase protective measures if Chinese software comes close to reaching the same technological level as foreign competitors. Political interference will aim to provide an additional push for Chinese brands. Chinese industrial software companies are already lobbying for more governmental support, for instance through exclusive government procurement of Chinese solutions or through more systematic and reliable financial support.[48]

Outlook

Chinese software developers will increasingly be able to provide complex software solutions. Even if the Chinese enterprises do not reach the same level of sophistication as foreign competitors, they will increasingly be able to provide tailored solutions for large Chinese corporations. The growing group of hopefuls will become especially important customers for them.

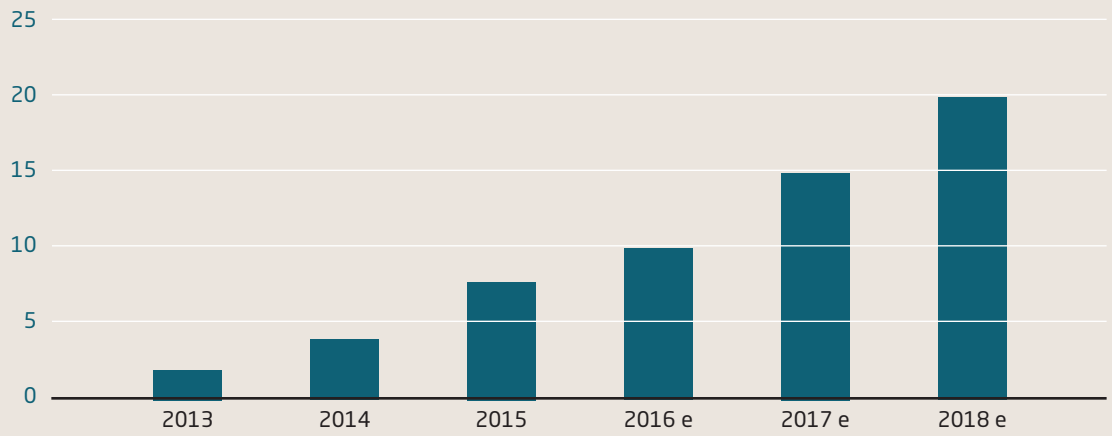
However, technology substitution will not proceed as quickly as in robotics. The reason for this is neither the lower level of political support nor the lower technological level, but technology lock-in. Chinese software providers frequently point to international providers restricting the compatibility of their products with other international software solutions. In fact, lock-in effects are strong for industrial software: once a company has implemented and integrated a certain solution into its organisational culture, it is very costly and time consuming to replace the software system with an alternative product. Although the majority of China's large companies consider using Chinese software solutions, they often end up using software from well-known and more popular international brands.[49]

CASE STUDY 3: 3D PRINTING

Many definitions of Industry 4.0 do not include 3D printing. However, similar to networked production, additive manufacturing is a very promising technology with the potential to revolutionise industrial production and many other fields such as medicine. Different from industrial software and robotics, 3D printing is a relatively immature technology. It is only at the early stage of commercialisation and the formation of a market. The industrial applications for 3D printing are currently limited to the manufacture of prototypes, spare parts and special parts. China's entire market for 3D printers, including industrial and non-industrial uses, has doubled annually for the last six years and a market value of 20 billion CNY is predicted for 2018 (Figure 17).[50] Within the next 5 to 10 years, China will become the biggest market for 3D printing worldwide.[51]

Figure 17

Huge growth potential of 3D printing in China
3D printing market development in China (in billion CNY)



Source: Qianzhan, (from 2016 onwards estimates only)

Technology gap and market shares

When it comes to industrial 3D printing, Chinese enterprises are less advanced than foreign competitors. Core components for industrial printers and high-end printing materials such as resin, ceramic and polymer powder are mostly imported from foreign suppliers.[52] This situation is mirrored in China's corporate landscape. Even though about 200 new enterprises have surfaced in the dynamic 3D printing market, only about ten currently work on developing 3D metal printers.[53]

The slightly backward position of Chinese enterprises is, however, not as obvious as in robotics and industrial software. As the technology is rather immature, international players are not yet as dominant as in other industries. Innovations for industrial applications can still rearrange the market structure profoundly and suddenly.

Chinese strengths

Despite a certain backwardness, Chinese enterprises are close to catching up to the international advanced level in industrial 3D printing. In contrast to robotics and industrial software, Chinese enterprises do not focus primarily on low-cost solutions and adaptation to Chinese customers' demands. Instead, Chinese companies have already built up some competitiveness in certain areas. This includes printing methods like selective laser sintering (SLS) and selective beam melting (SBM)[54] that use aluminium alloys, materials suitable for the aerospace industry due to their lightness and resistance to corrosion.

Chinese research institutions and enterprises are already among the global leaders in non-industrial uses for 3D printers. Chinese 3D printers for private consumers and for bio-printing are very advanced. Ground-breaking achievements by Chinese companies and research institutes in 3D printed body organs and tissue, housing structures and automobiles are regularly reported in the news.[55]

Political support

The emerging industry of professional 3D printing is mainly government-driven.[56] Compared to robotics and industrial software, however, government support for industrial 3D printing is less apparent and focuses more on R&D than on commercialisation. In 2013, the Ministry of Science and Technology (MoST) identified it as a core future technology in its 863 plan.[57] In February 2015, the MIIT, the NDRC and the Ministry of Finance jointly issued the first national development plan to promote additive manufacturing,[58] leading to a massive expansion in the field. In 2016, the central government pledged a total of more than 400 million CNY in funding for several R&D projects for 3D printing over four to five years.[59] Government programmes especially emphasise aviation and metal printing as key areas. Government support will increase over the coming years as the technology becomes more mature.

International cooperation

Several Chinese 3D printing companies have started to cooperate with foreign counterparts. They are less focused on acquisitions than the robotics industry. The Chinese 3D printing manufacturer Kangshuo built a joint venture with the U.S. company Solidscape. The Chinese company Meimai cooperates with the German industrial 3D printing company Voxeljet.[60] Hangzhou Shining put itself on the map of 3D bio printing in 2015 by acquiring intellectual property rights for a 3D printer for liver samples and by expanding into the field of high-quality materials.[61]

Outlook

It is very likely that Chinese 3D printing companies will quickly emerge as important market players domestically and globally, faster than in other advanced production technologies. This is due to the dynamic development of the immature technology and increasing government support.

There are several frontrunners likely to emerge as important global players: the most promising are Beijing Tiertime, Farsoon and Zhuhai CTC Electronic. The Hunan-based Farsoon, for instance, produces SLS machines that are the first industrial printers with Chinese technology to compete on the European market.[62] The company also provides printing material for SLS and recently collaborated with German chemical producer BASF on developing a new high-performing material.[63]

Another game changer will be Zhuhai CTC Electronic. With the backing of Zhuhai city, CTC built China's largest factory for 3D printers and recently launched two lines of industrial printers, including 3D metal printing.[64] While companies in industrial countries own most patents for metal printers, CTC has become the first Chinese firm to develop its own proprietary metal printing technology.[65]

6. Implications for industrial countries

KEY FINDINGS

- China's industrial policy will have an enormous impact on many industrial countries. Countries in which high-tech industries contribute a large share to the industrial output are most exposed to Made in China 2025.
- Following the current gold-rush period for foreign businesses in China, China's industrial agenda will negatively impact foreign tech suppliers and manufacturers in the years ahead.
- The Chinese state promotes investment in leading foreign technology enterprises with the aim of systematically acquiring cutting-edge technology and generating large-scale technology transfer. It is a realistic scenario that the widespread technology absorption by China will contribute to the erosion of industrial countries' technological leadership in specific industries.
- At the moment, China is still a relatively open market for greenfield investment of foreign tech suppliers in smart manufacturing. However, if protectionist measures increase, they will pose a serious long-term risk to foreign tech suppliers.
- The Chinese government's tight control of cyberspace affects the use of digital business applications, hinders the transfer of data and exposes sensitive business information to the grasp of the state.

Chinese smart manufacturing users and suppliers will contest the market positions of established international enterprises.

China's high ambitions and extensive political support for the manufacturing sector will reshape global competition structures. Despite the weaknesses of China's top-down policy, a group of Chinese companies will be able to utilise the political support effectively and significantly boost their competitiveness. And these emerging companies will continue to enjoy intense state support. The Chinese state will seek to shield their activities from international competition at home and to support their engagement on global markets politically as well as financially. The global competitive playing field will be effectively tilted by Chinese industrial policy.

This poses a number of fundamental challenges to industrial countries and international enterprises. China's industrial policy aims at technological leadership in industries that currently represent the foundation of these countries economic growth. In the near future, Chinese smart manufacturing users and suppliers will contest the market positions of established international enterprises both within and outside China.

6.1 INDUSTRIAL POLICY MEASURES CHALLENGE FOREIGN COMPANIES

As the previous chapters have shown, Chinese industrial policy uses a broad mix of traditional instruments to protect Chinese companies from international competition. This includes market access restrictions for international companies as well as subsidies and public procurement regulations favouring Chinese enterprises. These instruments are increasingly complemented by a set of nuanced policy measures tailored to the technical and regulatory specifics of smart manufacturing.

Four types of policy interventions will present a particular challenge to foreign enterprises and governments: state-driven outbound foreign direct investment in high-tech industries, state-controlled data flows, market access restrictions and China's strategic use of standardisation.

CHALLENGE 1: TECHNOLOGICAL HOLLOWING OUT BY STATE-DRIVEN FDI

The rapidly growing inflow of Chinese FDI into Europe and the United States has broadly positive effects on the host countries. Many acquired enterprises benefit significantly from the inflow of capital and welcome potential opportunities to better develop their business in China. The managers of many enterprises report that they have retained independent decision making after the acquisitions.

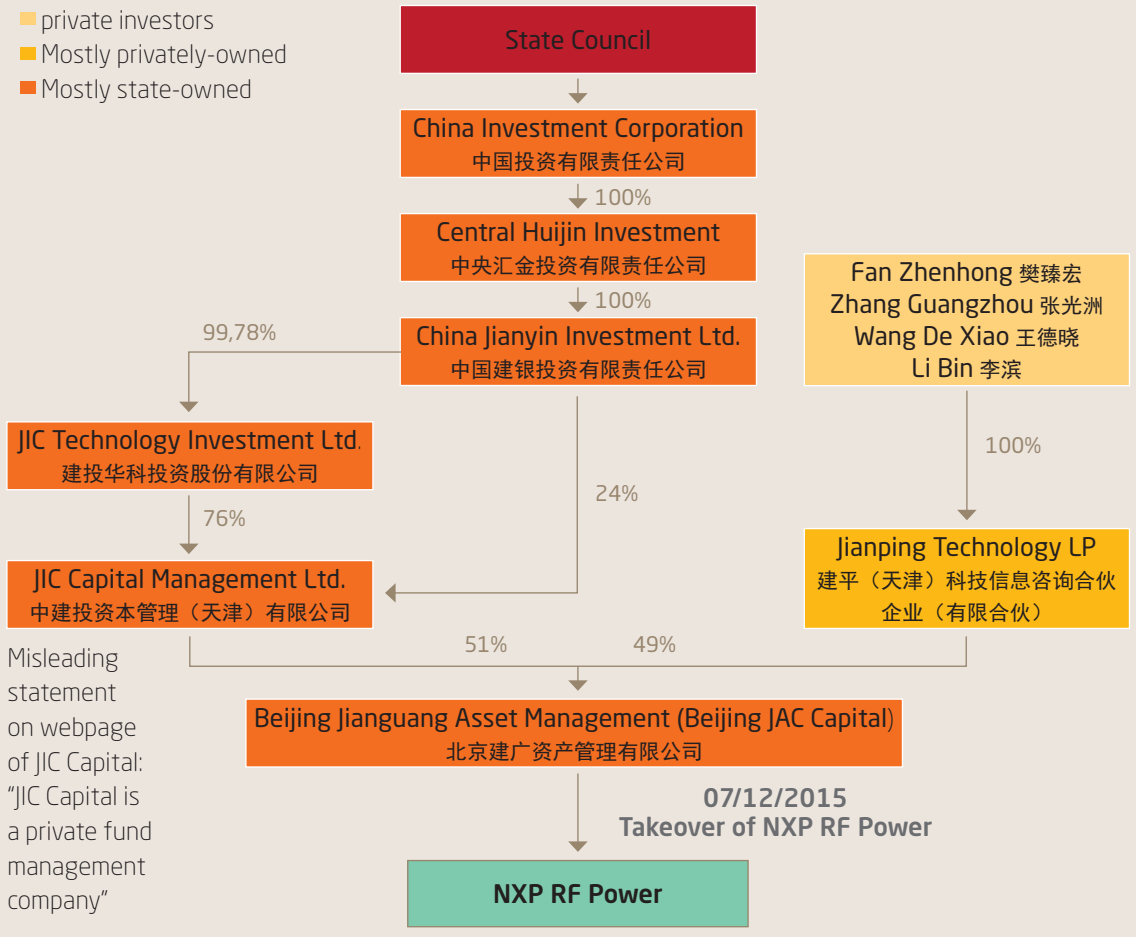
However, this overall positive impression is overshadowed by a newly emerging trend: strategic and technology-seeking FDI guided and supported by the state. The Chinese state promotes investment in leading foreign technology enterprises with the aim of systematically acquiring cutting-edge technology and generating large-scale technology transfer. Since state-led FDI in high-tech sectors is a new phenomenon, its full extent and precise effects are not yet entirely clear. But it is a realistic scenario that the widespread technology absorption by China will contribute to the erosion of industrial countries' technological leadership in specific industries.

China's "going out" policy emphasises international investment as a critical step towards building Chinese champions with global influence. There are strong indications that the absorption of advanced technology is an increasingly prevalent motive for the state's push for outbound FDI. From this perspective, Made in China 2025 can be read as a grand strategy for technology-seeking investment.

Figure 18

The state hides behind investment management companies

Ownership relations of Beijing JAC Capital Ltd., investor in NXP's RF power business in 2015



Source: MERICS

Table 7

Growing number of acquisitions of foreign tech suppliers

Investment by Chinese enterprises in foreign companies specialising in automation and digitisation of industrial production

Date	Chinese Investor	Foreign Target	Country	Share
Dec 2013	AVIC*	KHD Humboldz Wedag	Germany	79%
Jun 2014	Preh (Subsidiary of Joyson Electronics)	IMA Automation	Germany	100%
Dec 2014	Wolong Electric	SIR Solutions Industriali	Italy	89%
Jan 2015	Huachangda Intelligent Equip. (HCD)	Shanghai DEMC/ Dearborn Mid-West Company (DMW)	United States	100%
Jan 2016	ChemChina*	KraussMaffei machine tools	Germany	100%
Mar 2016	Siasun*	Teutloff	Germany	100%
Apr 2016	Wanfeng	Paslin	United States	100%
Apr 2016	AVIC*	Aritex	Spain	95%
Apr 2016 (announced)	Wuxi Lead Intelligent Equipment Co.	JOT Automation	Finland	100%
May 2016	Shanghai Electric*	Manz	Germany	19,67%
May 2016	Dongfang Precision	EDF EUROPE S.R.L.	Italy	100%
Jun 2016	Agic Capital	Gimatic	Italy	N/A
Aug 2016	Shanggong Group	H. Stoll	Germany	26%
Aug 2016	Midea	Kuka	Germany	94,5%
Oct 2016	Shanghai Electric*	Broetje Automation	Germany	100%
Withdrawn	FGC Investment	Aixtron	Germany	N/A

Notes: * = State-owned enterprises (share of state institutions >50%)
Source: MERICS research

The Chinese leadership's increasing interest in technology-seeking FDI is apparent from the discourse in Beijing policy circles: Ding Wenwu, head of the Electronic Information Technology Department of the MIIT and the National IC Fund, which actively invests abroad, said that "international acquisitions are often also an opportunity to attract foreign talent and to acquire technology".[66] Wang Xiaohong, a researcher at the government-based China Center for International Economic Exchanges, stated that investment in Europe is especially suitable when seeking to "acquire global advanced technology and create spill-over effects".[67]

The ambitions of the Chinese state become visible through its actions: Chinese FDI in high-tech industries with direct or indirect links to state entities has significantly increased in recent years. Since Made in China 2025 was released in 2015, investment in European smart manufacturing suppliers by Chinese state-owned enterprises as well as by private enterprises partially supported with state capital has risen rapidly (Table 7). The quest for foreign technology at times

even targets entire industries: for instance, almost all of the large semiconductor enterprises in the United States have received investment offers from Chinese state actors.

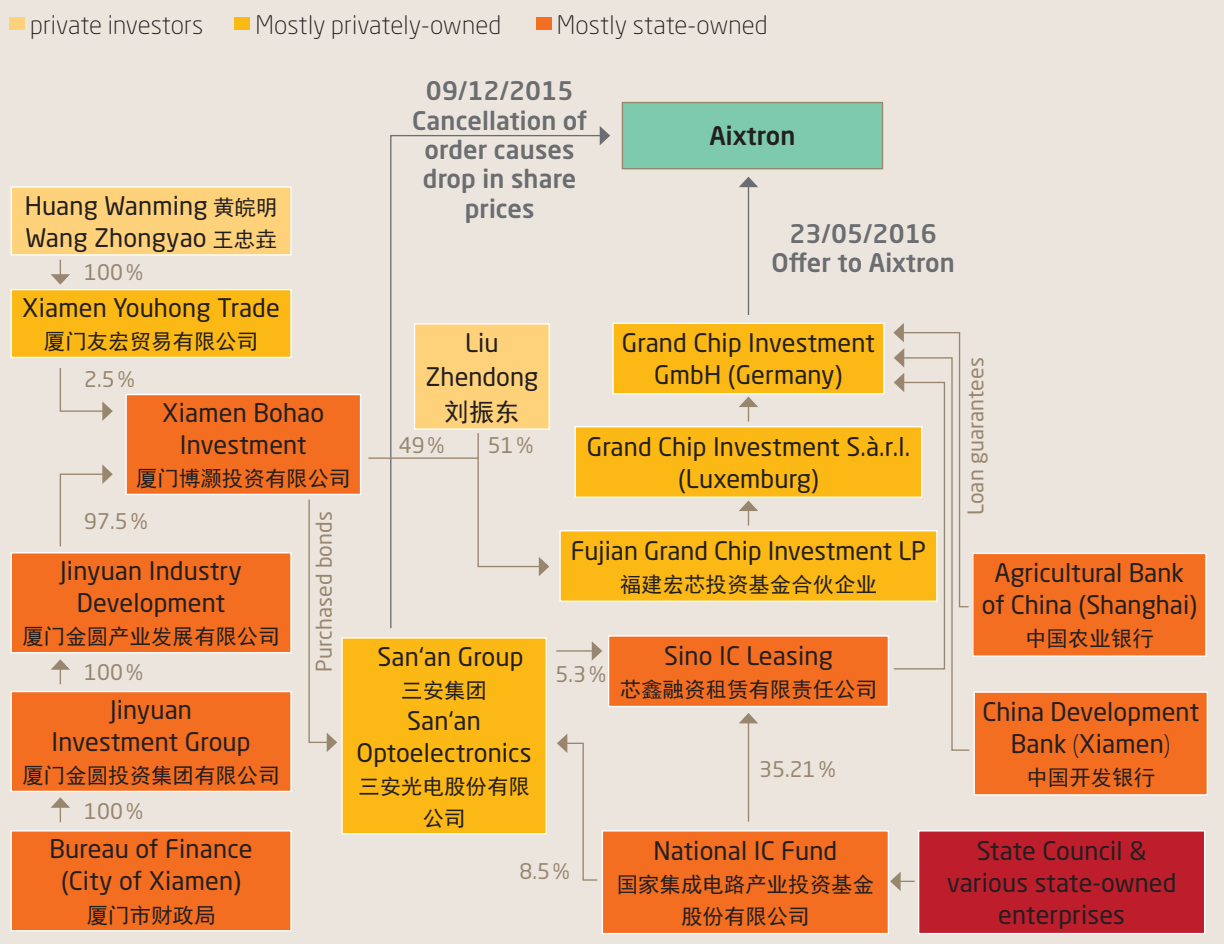
Sovereign investment funds and governmental investment management companies play an increasing role in high-tech FDI. While these funds and their management often present themselves as private enterprises, the state's active role is concealed behind an opaque network of ownership and funding structures. The State Council and local governments primarily use these funds and the expertise of private managers to make subsidies to Chinese enterprises more efficient. These funds are now becoming increasingly active with regard to investment in overseas markets. Examples of such funds and investment vehicles are the National IC Fund and the China Investment Corporation and its subordinate funds. One example of an investment by a Chinese state-owned investment corporation is the acquisition of the radio frequency power business of Dutch semiconductor enterprise NXP by JAC Capital Ltd., of which an investment vehicle of the State Council owns 51 per cent (Figure 18). The China Investment Corporation also contributed 550 million USD to the Asia-Germany Industrial Promotion Capital (AGIC), a private Chinese-owned investment fund based in Germany targeting investment in European Industry 4.0 enterprises.[68]

It is very likely that state-led FDI aiming at technology absorption will further increase in the coming years. With regard to smart manufacturing, the newly created Advanced Manufacturing Fund will probably also make investments abroad.

Figure 19

The Fujian connection

The network of potential state and private investors behind the bid for machine maker Aixtron



Source: Capital, MERICS

As technology-seeking state-led FDI becomes more pronounced, it creates a serious challenge for industrial countries. Regardless of the implications for national security and geopolitical considerations, this kind of investment could undermine their technological leadership in several high-tech industries. Large-scale investment in industries such as smart manufacturing equipment potentially opens the door for systematic technology transfer: with a certain time lag, state-driven FDI in high-tech enterprises is likely to cause an absorption of knowledge, talent and patents by Chinese enterprises.

A hollowing out of the technological leadership of industrial countries in pillar industries is possible.

If Chinese enterprises prove capable of using this technology effectively, a hollowing out of the technological leadership of industrial countries in pillar industries is possible. The duplication and transfer of technology from Europe or the United States to China is a realistic scenario. An example is the takeover of the American permanent magnet manufacturer Magnequench in the late 1990s by the state-owned enterprises China National Non-Ferrous Metals Import and Export Corporation and San Huan New Material, a subsidiary of the Chinese Academy of Sciences. After the Chinese investors had taken over Magnequench, they duplicated the production facility in China and closed down the site in the United States. In part due to this acquisition, China emerged as the largest manufacturer of permanent magnets worldwide, whereas there is no longer any significant production of these critical high-tech components in the U.S.[69]

RECENT CONTROVERSIES OVER CHINESE HIGH-TECH INVESTMENT IN EUROPE

Midea and Kuka

Two recent bids for high-tech enterprises ignited a controversial debate about Chinese FDI within political and economic circles in Europe. The first was the bid that led to the acquisition of robot maker Kuka by the Chinese electrical appliance manufacturer Midea. Kuka is a German flagship enterprise for Industry 4.0 technology. Although Midea promised not to transfer Kuka's intellectual property rights until 2023, it is likely that the enterprise's knowledge and abilities will be transferred to Midea in the long term.

From a national strategic perspective, a transfer of knowledge from Kuka to Midea will harm Germany's position in the robotics industry. However, from a business perspective the Midea-Kuka deal represents a rather unproblematic form of investment: Midea is a mostly privately-owned company that purportedly financed the deal privately.

Fujian Grand Chip Investment and Aixtron

The failed attempt by Fujian Grand Chip Investment (FGC) to take over the German machine maker Aixtron is a much more complex case (Figure 19).[70] Aixtron is one of two global producers of machines required to produce semiconductors for photovoltaics and LEDs, among other applications. The owner of FGC is a private businessperson, Liu Zhendong. However, the opaque network of ostensibly private investors of FGC actually conceals the Chinese state as an important investor and lender: the central government-controlled Sino IC Leasing, a subsidiary of the National IC Fund, offered to provide a loan of 500 million EUR to make the deal possible.[71] The other state actor involved is Xiamen Bohao Investment, an investment enterprise owned by the city government of Xiamen.

Even more alarming is the fact that Aixtron was faced with a tumbling share price after the Fujian-based San'an Optoelectronics cancelled a large order of machines in late 2015. Aixtron had already incurred big losses before, but this cancellation was the final trigger that caused the enterprise to seek a new investor. Some facts point to a close relationship between the customer San'an and the potential investors FGC and the National IC Fund. The parent company of San'an Optoelectronics, the San'an group, owns shares in Sino IC Leasing. Moreover, San'an Optoelectronics previously received a National IC fund investment of 9 per cent. Xiamen Bohao Investment also previously bought bonds of San'an.

CHALLENGE 2: DATA AND CYBER REGULATIONS PUT MANUFACTURERS' INDUSTRIAL DATA AT RISK

Smart manufacturing relies heavily on the generation, transmission and storage of sensitive business and production data. Accordingly, the integrity and safety of data flows is key to the operation of smart manufacturing processes. In this respect, China provides a very unfavourable digital environment for foreign enterprises. The Chinese government's tight control of cyberspace affects the use of digital business applications, hinders the transfer of data and exposes sensitive business information to the grasp of the state.

China has rigid written and unwritten rules and measures for cyber governance. The government sees control of data as a key instrument for protecting the predominant political role of the party. The enormous censorship system extensively filters all digital communication. The government seeks to tightly control encryption methods and to force companies to reveal encryption codes to the authorities. Sales or commercial use of encryption devices by foreign enterprises have to be authorised by the Office of State Commercial Cryptography Administration (OSCCA). Today, restrictions on the use of encryption devices are already highly problematic for foreign companies. In practice, it is very difficult for foreign enterprises to obtain these licenses.

With the development of the Internet of Things and the broad use of smartphones, the tracking of private information by the state is about to penetrate every aspect of social and economic life. For example, all electric vehicles in China already have to transmit position information to Chinese government agencies every few seconds.[72] The intensifying penetration of industry by digital applications and the corresponding increase in available data is also highly likely to spur an increase in the collection of different kinds of production data by state institutions.

China has rigid written and unwritten rules and measures for cyber governance.

These regulations and measures are very harmful to foreign business in smart manufacturing. First, foreign enterprises have to take into account that the Chinese state can have systematic access to sensitive business data, as enterprises might be required to open their systems to the Chinese state. It is possible that government institutions will also use the obtained data to inform Chinese companies about the knowledge and secrets of foreign competitors.

Second, enterprises have to operate in legally grey areas to protect their data. Restrictions on the use of encryption devices force some foreign enterprises to illegally circumvent these regulations to ensure their data is protected.

Third, the low internet speed of connections to foreign servers and the regulations on encryption render internet communication and many smart manufacturing business models ineffective. For instance, remote maintenance of machines (smart services), which involves the transmission of encrypted sensitive machine data to and from service centres outside of China, is difficult to carry out under the current regulations.

Tight cyber governance is likely to remain in place. The new Cyber Security Law, released in November 2016, contains a provision that customer data pertaining to critical infrastructure should be stored and processed within China. Critical infrastructure is defined as communication technology, energy, transport, water supply, financial services and public supply facilities. Mandatory storage of sensitive data in China entails serious security risks for the data owners. The local storage requirement gives the Chinese state easy access to the data of international companies. In addition, technical weaknesses in the Chinese server infrastructure increase the vulnerability to cyber attacks.

CHALLENGE 3: INCREASING MARKET ACCESS RESTRICTIONS FOR TECH SUPPLIERS

At the moment, China is still a relatively open market for the greenfield investments of foreign tech suppliers into smart manufacturing. The state explicitly encourages foreign investment into areas such as industrial robots or high-end machine tools. However, Chinese market access regulation typically follows strategic industrial policy goals: markets are initially open to attract foreign technology, to help technological progress and to facilitate learning from foreign enterprises. Once Chinese companies are making significant progress in closing the technology gap, the Chinese government seeks to increase their market share by erecting barriers to foreign market

activities. If market access regulation follows this pattern in the case of smart manufacturing, it will pose a serious long-term risk for foreign tech suppliers.

China's government is already closing the market for information technologies. The Multi-Level Protection Scheme, for instance, has constrained the use of foreign-produced security applications in state institutions since 2007. After the Snowden revelations, the Chinese government tightened its restrictions for foreign information technology. E-commerce and cloud computing – software as a service (SaaS) and software as a platform (SaaP) – companies must comply with restrictive rules in order to receive Internet Content Provider (ICP) licenses.[73] As a matter of fact, few foreign products obtain the necessary licenses. Foreign tech suppliers such as Cisco, IBM and Qualcomm have already been hit hard by the successive closure of the IT market. As industrial machines become more and more digitised and connected to the internet, government interference in the IT market will have a growing impact on the machinery industry.

Furthermore, foreign tech suppliers will be increasingly affected by new regulations that certify "trustworthy products". The rules for "secure and controllable" ICT products affect foreign businesses in many sectors. As of today, foreign products are, for instance, not included in the lists of cloud services labelled as trustworthy.[74] For now, this has limited impact on foreign enterprises' business opportunities. These certification systems will, however, play a role in the state's construction of the so-called Social Credit System (社会信用体系). Based in particular on big data analysis, the Social Credit System is intended to rate companies depending on their economic and social trustworthiness.[75] The system is meant to regulate the market and to restrict market access, excluding those who are defined as not trustworthy based on the Chinese leadership's rules. If the Social Credit System is implemented successfully, it will evolve to be a powerful new tool that restricts the business activities of foreign tech suppliers in strategically important sectors such as industrial e-commerce and software.

CHALLENGE 4: DOMESTIC STANDARDS SUPPORT INDUSTRIAL POLICY GOALS

China is generally willing to harmonise its national standards with international standards, which would facilitate market access for foreign businesses. The ongoing reform of its standardisation system and the revision of the Standardisation Law point to a liberalisation and internationalisation. Private actors are encouraged to set industry standards and regulators are encouraged to collaborate with their international counterparts. There are positive examples of joint standardisation initiatives with China. Active standardisation dialogues for Industry 4.0 exist, for example, between China and Germany. The Chinese reference architecture for smart manufacturing is very similar to the German standardisation reference architecture for Industry 4.0 (RAMI 4.0).[76] This provides a window of opportunity to promote European standards and to facilitate market access for foreign enterprises.

China is generally willing to harmonise its national standards with international standards.

Similar to other countries, China is strengthening its efforts to influence and set international standards in order to support the export of Chinese technologies and reduce the burden of paying royalty fees for international patents. Although this increases competition with China in standardisation, this occurs within established international organisations. Due to the large Chinese market for smart manufacturing, it is likely that China will become an influential force in relevant international committees. In the case of smart manufacturing, China has already scored a success by introducing its process and factory automation standards (WIA-PA and WIA-FA) under the International Electrotechnical Commission.[77]

At the same time, China sometimes formulates national standards in strategic industries that deliberately differ from international standards in order to impede market access for foreign technology and to favour Chinese technology on the domestic market. Examples of Chinese national standards are the FDD-LTE standard for 4G mobile networks, the WAPI standard for wireless networks and independent standards for electric vehicle charging stations. If such a national path of standardisation also manifests itself in smart manufacturing, market access for foreign tech suppliers could be considerably restricted. The standardisation reform gives more weight to enterprise-led committees in standards setting. However, it is possible that state-owned enterprises and state-dominated associations use their increased influence to introduce standards that make

market activities for foreign enterprises more difficult.

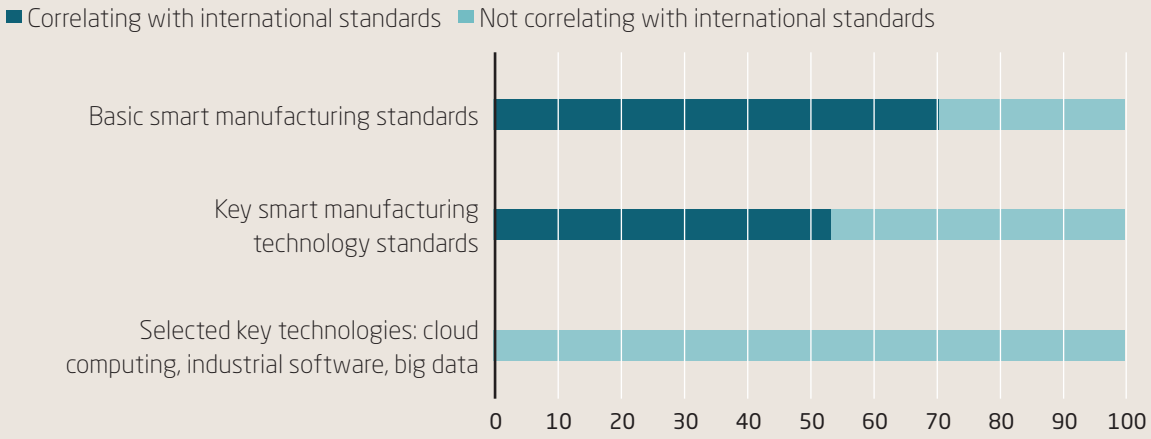
This specifically relates to technologies with strong data security concerns like cloud computing, industrial software and big data. It is concerning that Chinese smart manufacturing standards for key technologies show a low correlation with international standards when compared to more basic smart manufacturing standards, which are less important for controlling a technology (for instance, safety and management requirements) (Figure 20).

In the worst case, nationally independent standards would cut off foreign machinery makers and software developers from the Chinese market in some strategically important technologies. Alternatively, these enterprises would have to use the Chinese standards and pay royalty fees for providing products using the Chinese standards in order to maintain a presence in the Chinese market.

Figure 20

China goes its own way in cloud computing and big data

Percentage of Chinese standards correlating with internationally agreed standards in various categories



Source: SAC

6.2 MADE IN CHINA 2025 COULD HARM BUSINESS OF FOREIGN ENTERPRISES

Following the current gold-rush period, China's industrial agenda will negatively impact foreign tech suppliers and manufacturers in the years ahead, irrespective of the strategy's ultimate level of success. The degree of the negative impact will, however, vary substantially between different technologies and industries and depends on the pace and effectiveness of the implementation of Made in China 2025. Eventually, any scenario for Made in China 2025 will lead to higher competition from China and a significant decrease in business opportunities for foreign companies as these will increasingly be affected by Chinese industrial policy (Table 8).

Tech suppliers

China's political agenda to support smart manufacturing will greatly enhance business opportunities and create "golden years" for foreign tech suppliers at first. In a second phase after 2020, however, the Chinese government will take steps to restrict market access as soon as Chinese are able to compete with their own domestic products. The government will increase political intervention in the market and will try to squeeze out international competitors. If successful, this will lead to a third phase after 2025, in which Chinese companies become strong competitors in China and on global markets (scenario I). If Chinese companies fail to catch up, foreign tech suppliers will continue to have market opportunities in China but they will face political intervention and an unfair market environment (scenario II). Scenarios I and II might both come to pass at the same time, though for different technologies and industries.

Table 8

Future impact of China's industrial policy on foreign manufacturers and tech suppliers

The three phases of China's catch-up process and their implications for foreign companies

Developments in China	Impact on foreign tech suppliers		Impact on foreign manufacturers	
	Opportunities	Challenges	Opportunities	Challenges
Phase I: Golden years (approx. 2016-2020)				
Policy-induced demand for smart manufacturing	Large business opportunities	Slightly growing competition from new Chinese competitors	China as laboratory to test smart manufacturing; qualitative improvement of Chinese supply chain	Competition from frontrunners
Preparation of and experiments with stronger industrial policy measures	Possibility to influence design of future policy measures	Gradually increasing business restrictions		
Growing state-backed overseas FDI in high-tech industries	New funding sources; access to the Chinese market	Technology drain		
Phase II: Market closure (approx. 2020-2025)				
Strong enforcement of industrial policy measures prepared during Phase I		Strong and unfair competition		Restrictions on the use of foreign IT products and infrastructure
Continued massive government funding	Large business opportunities	Overcapacities among Chinese enterprises; price deterioration	Chinese spending lowers prices for smart manufacturing technologies	Stronger competition from Chinese frontrunners and hopefuls
Chinese companies use technologies and know-how acquired in Phase I to enhance their competitiveness	Accelerating technology transfer to China due to Chinese investments during Phase I	Strong Chinese competitors selling high-quality products	Lower costs for high quality smart manufacturing technologies	
Political support for Chinese companies to expand to international markets		Increasing competition on international markets		Increasing competition on international markets
Phase III: Success or Failure of Made in China 2025 (after 2025)				
Scenario I – Success of Made in China 2025				
Lowering of market barriers for foreign enterprises	Improved market access		Improved market access	
Strong competitiveness of Chinese companies without government support		Strong competition, even in high-tech sector		Chinese enterprises challenge foreign market leaders across the board
Political promotion of international expansion		Lower market shares on home markets; loss of international high-tech leadership		Lower market shares on home markets; loss of international high-tech leadership
Scenario II – Failure of Made in China 2025				
Continuous market barriers for foreign companies		Unfair competition		Unfair competition
Large part of China's industry remains at a low level of smart manufacturing	High-tech market leadership remains	Drop in demand for smart manufacturing	High-tech market leadership remains	Strong competition, but only from a few frontrunners and hopefuls

Manufacturers

In the coming years until 2020, foreign manufacturers will continue to benefit from their enormous advantages in smart manufacturing. Only a few Chinese frontrunners will begin to challenge established multinational corporations, leading to a slow shift in market structures. As the Chinese policy gradually becomes effective during the second phase after 2020, however, more and more Chinese hopefuls will use advanced technologies to increase their leverage and to compete with their international counterparts on the Chinese market. Internationally, foreign manufacturers will still be able to maintain their leading position. Yet Chinese challengers will increase their competitiveness at high speed. If China's smart manufacturing agenda proves successful, a large group of hopefuls will become strong competitive players after 2025, both in China and worldwide. This will lead to significantly diminished market shares for established international corporations. If Made in China 2025 is not successful, the group of hopefuls challenging the market leadership of international corporations will be significantly smaller than in the case of success. Despite the increasing market shares of Chinese companies, foreign market leaders will be able to maintain their dominant roles in many industries.

6.3 CHINA'S INDUSTRIAL POLICY PUTS PRESSURE ON INDUSTRIAL COUNTRIES

China's industrial policy will have an enormous impact on the entire national economies of many industrial countries. These impacts will reach beyond smart manufacturing. China's industrial policy targets industries of fundamental importance for the economic growth of many industrial countries. If China's industrial policy is successful, these countries will experience lower GDP growth rates, job losses and a decrease in industrial output.

Countries in which high-tech industries contribute a large share to the industrial output are most exposed to Made in China 2025 (Figure 21). The Czech Republic, Germany, Italy, Hungary, Japan and South Korea will be most vulnerable if Made in China 2025 is successful, as outlined in scenario I. Their future economic growth relies heavily on industrial production. The high- and medium-tech industries that Made in China 2025 identifies as strategically important account for more than 40 per cent of their industrial value-added.

Chinese challengers will increase their competitiveness at high speed.

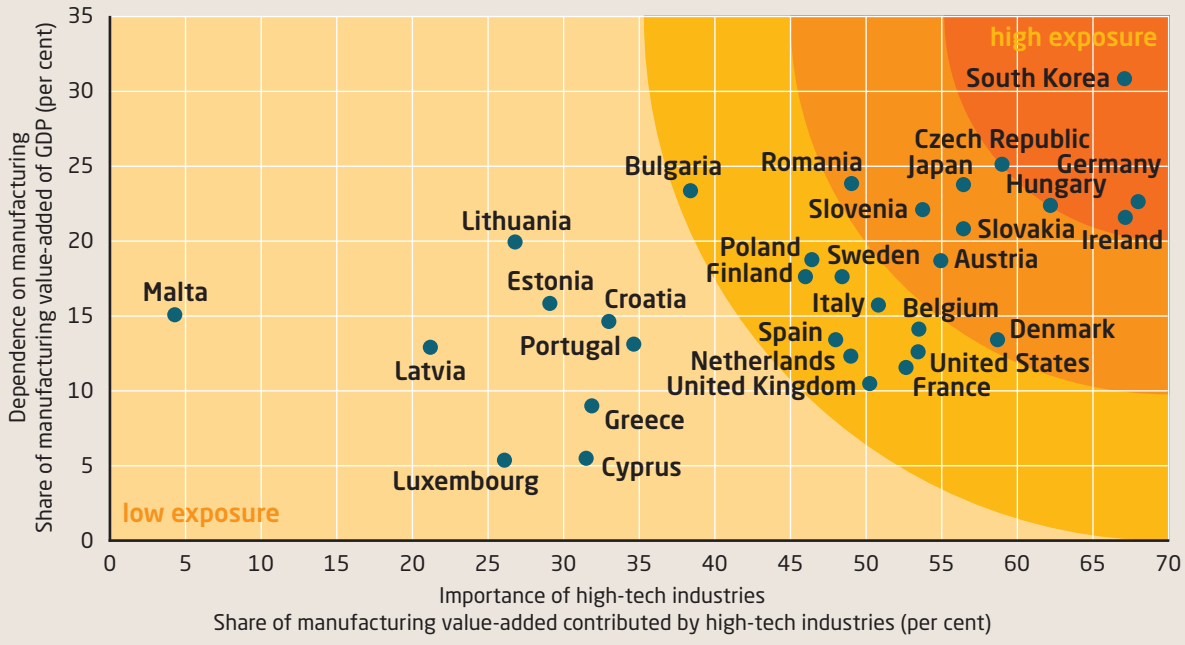
The largest industries that will be affected by China's industrial policy are automotive and machinery. Machinery is the most important high-tech industry for nine European countries, while the automotive industry is the largest high-tech industry in seven countries. Other important industries such as chemicals will also feel the impact of Chinese industrial policy.

For the countries that will potentially be most affected, a fast and coordinated response to China's strategic industrial policy related to Made in China 2025 is of the utmost importance. The success of Made in China 2025 is still uncertain as its implementation faces a number of difficulties and many policy measures are not yet set in stone. A timely reaction could still influence some measures and reduce the negative impacts on industrial countries and their companies.

Figure 21

Under Pressure: Industrialised countries will feel the heat of Made in China 2025

Vulnerability of select industrial countries to Made in China 2025



Source: MERICS

7. Recommendations

Made in China 2025 poses a great challenge to economies and enterprises around the world. Decision makers in Europe and the U.S. need to take the enormous potential of China's sophisticated industrial policy seriously in order to remain competitive against China's rapidly emerging, powerful enterprises. Policy makers, industry associations as well as suppliers, producers and users of smart manufacturing technology will have to react smartly to the challenges presented in Chapter 6. A swift and determined response will improve the prospects for international companies to grasp the opportunities presented by Made in China 2025 while containing its potentially detrimental impacts.

7.1 RECOMMENDATIONS FOR POLICY MAKERS

DEVELOPING NEW INSTRUMENTS TO ADDRESS STATE-DRIVEN FDI

Large parts of China's foreign direct investments (FDI) create significant benefits for the acquired companies and are largely unproblematic from a macroeconomic perspective. Europe and the United States should continue to welcome these investments.

State-led investments, however, increasingly aim at replacing global technology leaders by way of transnational takeovers and subsequent localisation of acquired technologies. China's technology acquisitions are often supported and guided by the Chinese state, using government financing and opaque investment networks. At the same time, China denies reciprocal market access for international investors. This undermines the principles of fair competition and exploits the openness of market economies (see Chapter 6).

It is a misunderstanding to lable government screening of state-led investments as protectionist. On the contrary, building the leverage to prevent market distortions would prove that policy makers are willing and able to actively defend liberal market principles, including openness to investment.

The existing instruments in Europe for reacting to problematic FDI are inadequate to address the emerging challenges. Policy makers need a refined set of options to effectively respond to different types of acquisition attempts. The options need to be non-discriminatory and apply equally to state-led investments from all countries. The following provides a menu of ideas for strengthening the existing policy toolbox.

FDI into Europe should be more comprehensively screened for national security implications.

Increase transparency by tightening disclosure requirements for state-led acquisitions. It is essential for sound decision making on FDI inflows to obtain more extensive and accurate information about the background of outside investors. Transparency is a prerequisite for calibrated state intervention and provides the basis for long-term adjustments of FDI screening regimes. Mandatory notification and disclosure requirements for state-owned or state-financed entities are indispensable for increasing transparency. The threshold for notification will have to consider the share taken in a company, the size of the investment and the involvement of the state. While the implementation of disclosure mechanisms is most feasible at the member state level, sharing information at the EU level will enhance the ability to react to EU-wide patterns of state-investment in high-tech sectors.

Extend the scope of national security screenings. Following the example of the Committee on Foreign Investment in the United States (CFIUS), FDI into Europe should be more comprehensively screened for national security implications. The current narrow set of criteria to determine what constitutes a national security concern could be widened to include additional sectors and products and should be updated to keep up with technological developments. Sensitive information is no longer limited to the defence industry in a narrow sense, but is increasingly shared within a wider circle of machinery and enterprise software suppliers. The increasing importance of cyberspace as a primary arena for conflict underlines the necessity to rethink the definition of national security with regard to foreign investment activities.

Use competition policy more broadly for reviewing state-owned investors. Existing competition policies at EU and member state level provide a basis for the regulation of investment. Expanding the application of EU state aid rules to all entities operating in the single market represents a pragmatic way for addressing Chinese and other external FDI in breach of competition rules. In addition, merger control procedures can be more broadly used for screening investments from state-owned enterprises by way of considering all state-owned enterprises from the same country as a single economic entity. In 2016, the European Commission set an example by investigating the extent of government control of China's state-owned China General Nuclear Power Corp before allowing investment in the Hinkley Point C nuclear power plant in the UK.

Establish reciprocity measures to address and negotiate Chinese investment barriers. When evaluating the necessity for state intervention, decision makers should also consider whether the partner country grants reciprocal access for inbound investment. Access should be granted or denied based on a sector-specific "equivalence of openness" test. Standards and thresholds for this course of action can for instance be based on OECD openness criteria and assessments. However, such a measure would be in breach of current EU law. A change of EU treaties would be necessary to allow interventions based on such „equivalence of openness" tests.

Screen state-led investments for systematic acquisition of essential high technology. A possible new mechanism could be a review of non-EU state-led FDI specifically in high-tech industries. FDI screening would be triggered by non-EU investments aimed at a politically motivated, systematic relocation of core technologies. Responsible state agencies would be allowed to attach conditions (e.g. barriers to technology transfer) to the completion of a transaction or to entirely block a deal in exceptional cases. This would require a major reform of the European investment regime to make technology-based interventions legally sound. Such a reform is currently politically highly unlikely.

MITIGATING CYBER RISKS

Europe and the United States need to further extend their cyber-security dialogues with China.

Foreign enterprises in China are insufficiently protected against the insecure digital environment in the country and the expansive collection of data by the state. Although enterprises can themselves improve their level of protection, only national European governments and the EU can mitigate the systemic cyber risks in China. The following responses can improve the protection of sensitive industrial data:

Leverage smart manufacturing cooperation to improve cyber-security dialogue. China's government actively strives for close international cooperation on smart manufacturing. This provides an opportunity for European governments to demand concessions from China in return. Making the political backing of cooperation with China on smart manufacturing conditional on substantial progress in the dialogue on cyber security will create leverage. This leverage can be used to demand, for instance, the adjustment of Chinese cyber policies that discriminate against or openly harm foreign businesses.

Deepen cyber-security cooperation. To improve cyber security in smart manufacturing, Europe and the United States need to further extend their cyber-security dialogues with China. While Chinese counterparts often prioritise the discussion of cybercrime, European and U.S. negotiators should shift the focus towards cyber security regulations and standards (for example, the implementing regulations for China's Cyber Security Law), encryption, data transmission, data storage and cyber-espionage. On the European side, this requires effective cooperation between national ministries of science, the economy and the interior as well as between member states.

Increase R&D investments in cyber defence capabilities. Increased public funding for the digital protection of industrial systems and enhanced R&D for IT security is essential for a strong industrial cyber defence capability. The use of digitised production makes industry more vulnerable to cyber theft of business secrets and sensitive information. Many cyberattacks originate from Chinese territory. Concrete measures to mitigate these risks include establishing new university programmes and research units for cyber security and increasing the focus of publically funded institutions providing cyber defence services to industry.

Implement a targeted industrial policy for crucial cyber technologies. As a pro-active response to China's strategic industrial policy, European policy makers should set out to design and implement a narrowly targeted industrial policy themselves, focusing on a small number of strategic infant industry sectors for which government promotional and protective policies would make the greatest difference. The top-priority sector for such a targeted programme is Europe's cyber defence industry at the EU and member state level. Significant public investments in cyber defence technologies would not only create crucial benefits for national and economic security. It would also generate spill-over effects boosting the broader advancement of viable European IT and AI industries.

Sustained public investment in European cyber defence businesses and start-ups would provide a much needed upgrade of protection against cyberattacks of state or non-state origin that carry increasing security, political and economic risks. Beyond the risks of military sabotage, this includes manipulation of democratic public opinion and elections, economic espionage, and technology theft.

Targeted public demand, through co-investment and public procurement, would catalyse the emergence of a network of collaborating cyber defence companies. This state-backed network would provide favourable and reliable economic conditions for crucial technology companies, making them less susceptible for takeover offers from abroad. In remaining cases of foreign acquisition attempts, the EU and national governments need to strictly apply existing provisions for state intervention: foreign takeovers of cyber defence-related hardware and software companies need to be thoroughly screened and, where necessary, prohibited on the grounds of national security concerns.

It is important to track whether and how China implements localisation targets on the ground.

EXAMINING THE CONFORMITY OF CHINA'S INDUSTRIAL POLICY WITH INTERNATIONAL LAW

Policy makers need ways to counteract the systematic closure of the Chinese market in important high-tech sectors. One potential method of achieving this is the investigation of Chinese localisation targets and subsidies and their compatibility with China's WTO obligations.

Investigate localisation targets. Europe as well as the United States should request from China an official clarification of the purpose, character and implementation of the localisation targets associated with Made in China 2025. These targets are mostly articulated in semi-official documents, and the Chinese government denies adopting any such instruments. Therefore, it is important to track whether and how China implements them on the ground. If it becomes clear that localisation targets are being implemented while bilateral consultations do not lead to tangible results, member states should examine whether those targets violate the stipulations on local content requirements and subsidies in trade agreements like the GATT, TRIMs, ASCM and TBT. If the examination comes to the conclusion that China is violating WTO rules and if China insists on pursuing its policy in bilateral consultations, the EU should consider filing a case with the WTO Dispute Settlement Body.

7.2 RECOMMENDATIONS FOR INDUSTRY ASSOCIATIONS AND CHAMBERS

INCREASING CHINA-RELATED ACTIVITY IN THE FIELD OF SMART MANUFACTURING

The following measures are geared toward improving the support that industry associations and chambers of commerce can provide to European enterprises regarding smart manufacturing:

Strengthen on-the-ground information-gathering. Decision makers urgently need more extensive and precise information on China's industrial policies applied in the context of Made in China 2025. Industry associations, through their presence on the ground, are in a good position to gather information and raise awareness on emerging smart manufacturing policies in China.

Improve information sharing and coordination. Industry associations and chambers of commerce from Europe, the United States and other OECD countries should improve information

sharing. The capacities of these stakeholders can only fully come into play if associations with a strong presence on the ground in China combine their interests. An example of an existing coordination platform is the United States Information Technology Office in Beijing. Joint action can improve the international stakeholders' ability to create leverage with regard to Chinese political decisions.

Increase information through intensified dialogue. Deepening exchange with Chinese smart manufacturing associations, industry partners and alliances as well as policy institutes will help provide early information about policy planning and implementation. Such dialogues can help solve technical issues that do not require decision making at the political level. Potential dialogue partners are the China Center for Information Industry Development (CCID), the Chinese Academy for Telecommunication Research (CATR), the National Alliance for the Development of the Industrial Internet and the Alliance for the Promotion of the Digitisation of Industry (for further potential partners see Figure 5).

DISSEMINATING AND ESTABLISHING INTERNATIONAL INDUSTRY STANDARDS IN CHINA

Use opportunities to influence standardisation processes. China is in an early stage of formulating standards for smart manufacturing. The technologically advanced level of European and American enterprises provides them with a chance to influence the Chinese standardisation process and to disseminate and establish international industry standards. Collaboration with China on standard formulation is a promising way to prevent the country from developing independent national standards that ultimately serve as technical barriers to trade and market access. Increasing the number of standardisation experts based in China would be a first step to improve associations' capacities. It will also be critical to participate in industry-based standardisation committees, which exert considerable influence on the on-going reform of the Chinese standardisation system.

7.3 RECOMMENDATIONS FOR SUPPLIERS OF SMART MANUFACTURING TECHNOLOGY

Foreign suppliers of smart manufacturing technology have to strike a balance between reaping the benefits of the demand boom in China and protecting essential knowledge and technologies. Regarding the risk assessments of foreign enterprises, several aspects are worth considering:

Prevent unidirectional technology transfer. Safeguarding core technologies will become even more challenging for foreign companies that apply smart manufacturing processes in China. Increasing digitisation in combination with weak data security makes core technologies highly vulnerable. An effective method of protection is to limit technical cooperation and digital integration with Chinese partners and suppliers to areas in which Chinese companies are already at an advanced technological level. Research partnerships will enable European and U.S. counterparts to learn from Chinese enterprises as well and to jointly create new knowledge in the form of patents and use cases. Promising areas for such collaboration include 5G mobile networks, wireless sensor networks, 3D printing, industrial e-commerce, cloud computing and big data.

Hedge against risk by expanding business outside China. In light of Made in China 2025, international suppliers of smart manufacturing technology need to consider how to reduce their dependence on the Chinese market. As soon as China's substitution strategy is in full swing and Chinese competitors are catching up technologically, business opportunities for foreign companies will sharply diminish. The active development of markets in Europe and the United States, as well as emerging markets such as India, can serve as a fallback option to complement engagement in China.

7.4 RECOMMENDATIONS FOR COMPANIES USING SMART MANUFACTURING

Advanced manufacturing technology will determine a company's international success. European and U.S. manufacturers must continually adjust their strategies to deal with this dynamic process. The following considerations can be helpful:

Avoid illusions about the technology gap. Complacency is a major risk for advanced industries. Currently, European and United States companies are still well ahead of most of their Chinese competitors in the use of smart manufacturing. But some Chinese companies, propelled by Made in China 2025, will quickly catch up. In order to avoid being caught off guard, European and United States companies need to maintain their focus on their own technological advancement, prioritising the further digitisation of their facilities. Although the business case for Industry 4.0 remains somewhat uncertain, curiosity and openness to technological change can prevent companies from being caught unprepared by breakthroughs of Chinese enterprises.

Coordinate for collective action. International companies in China need to explore ways of building leverage to influence the Chinese leadership's decision making on industrial policy and cyber security regulations in the context of Made in China 2025. Streamlining approaches among foreign companies, is one way to build leverage. In some cases, interests also align between foreign enterprises and their Chinese partners, opening additional opportunities for coordinated action.

Streamlining approaches among foreign companies, is one way to build leverage.

8. Annex

Table 9

List of implementation documents for Made in China 2025 in the field of smart manufacturing

Date of publication	Policy document	Releasing institution
19/05/2015	Made in China 2025 (中国制造2025)	State Council
21/07/2015	List for Smart Manufacturing Demonstration Projects 2015 (2015年智能制造试点示范项目名单)	MIIT
27/07/2015	Key projects 2015 to Transform and Upgrade the Industry (2015年工业转型升级重点项目指南)	MIIT
29/09/2015	Made in China 2025 Key Area Technology Roadmap (〈中国制造2025〉重点领域技术路线图(2015版))	MIIT
14/12/2015	Action plan (2015-2018) for Implementing the State Council's Guiding Opinions on Actively Advancing the Internet Plus Action Plan (贯彻落实《国务院关于积极推进"互联网+"行动的指导意见》行动计划（2015-2018年）)	MIIT
30/12/2015	Guideline for the Construction of a National Smart Manufacturing Standardisation System (2015) (国家智能制造标准体系建设指南（2015年版）)	MIIT, Standardisation Administration of China
01/04/2016	Implementation Plan for the Special Programme for Building National Champions in Single Commodities (制造业单项冠军企业培育提升专项行动实施方案)	MIIT
27/04/2016	Plan for the Development of the Robotics Industry (2016-2020) (机器人产业发展规划（2016-2020年）)	MIIT, NDRC, Ministry of Finance
04 /07/2016	List for Smart Manufacturing Demonstration Projects 2016 (2016 年智能制造试点示范项目名单)	MIIT
26/07/2016	Guideline for the Special Programme for Developing a Service-Oriented Manufacturing (发展服务型制造专项行动指南)	MIIT, NDRC, Chinese Academy of Engineering
26/08/2016	Guideline for the Special Programme on Promoting the Upgrading of Quality Brands of the Equipment Manufacturing Industry (促进装备制造业质量品牌提升专项行动指南)	MIIT, General Administration of Quality Supervision, Inspection and Quarantine, State Administration for Science, Technology and Industry for National Defense
30/08/2016	Guiding opinions on Improving the Innovation System of Manufacturing and Promoting the Establishment of Manufacturing Innovation Centres (关于完善制造业创新体系，推进制造业创新中心建设的指导意见)	MIIT
02/09/2016	List of Pilot Demonstration Projects for the Chinese-German Cooperation on Smart Manufacturing (中德智能制造合作2016年试点示范项目名单)	MIIT
21/09/2016	Special Programme for Innovative Development in Smart Hardware Industry (2016-2018) (智能硬件产业创新发展专项行动（2016-2018年）)	MIIT, NDRC
21/10/2016	Development Plan for Innovation Capacity in Industrial Technology (产业技术创新能力发展规划)	MIIT
22/10/2016	Guideline for Key Projects of Industrial Upgrading (Made in China 2025) in 2016 (关于发布2016年工业转型升级（中国制造2025）重点项目指南)	MIIT
07/11/2016	Guideline for Intellectual Property Rights in Manufacturing Innovation Centres (制造业创新中心知识产权指南)	MIIT
08/12/2016	Smart Manufacturing Development Plan (智能制造发展规划（2016-2020年))	MIIT, Ministry of Finance

ENDNOTES

1 | IFR [International Federation of Robotics] (2015). "World Robotics 2015 Industrial Robots". http://www.ifr.org/industrial-robots/statistics/. Accessed: July 15, 2016. Different from IFR data, our calculation for China also includes migrant workers in addition to regular workers.

2 | IFR [International Federation of Robotics] (2015). "World Robotics 2015 Industrial Robots". http://www.ifr.org/industrial-robots/statistics/. Accessed: July 15, 2016; CCID [China Center for Information Industry Development] 赛迪工业和信息研究院 (2015). "云计算发展白皮书(2015 年)" (White paper on cloud computing development (2015 edition)). April. http://www.chinacloud.cn/upload/2015-10/15102014214779.pdf. Accessed: July 15, 2016; CCID [China Center for Information Industry Development] 赛迪工业和信息研究院 (2015). "大数据发展白皮书(2015 年)" (White paper on big data development (2015 edition)). April. http://www.ccidwise.com/uploads/soft/150421/DATA.pdf. Accessed: July 15, 2016; CCID [China Center for Information Industry Development] 赛迪工业和信息研究院 (2016). "2016 年中国工业无线传感器网络产品市场应用趋势" (2016 trends in the market of Chinese industrial wireless sensor network products). August 15. http://www.ccidgroup.com/sdgc/7742.htm. Accessed: July 15, 2016.

3 | STAUFEN AG (2015). "China – Industrie 4.0 Index 2015." November 2. http://www.staufen.ag/fileadmin/hq/survey/STAUFEN.-studie-china-industrie_4_0-index-2015-DE.pdf. Accessed: July 18, 2016.

4 | State Council 国务院 (2016). "李克强主持国务院专题讲座讨论加快发展先进制造与3D 打印等问题" (Li Keqiang heads State Council expert symposium to discuss the acceleration of the development of advanced manufacturing and 3D printing technology). August 23. http://www.gov.cn/guowuyuan/2015-08/23/content_2918394.htm. Accessed: August 25, 2016.

5 | MIIT [Ministry of Industry and Information Technology] 工业和信息化部 (2016). "业和信息化部关于引 发纺织工业发展规划(2016-2020 年)的通知" (Notice of the MIIT on publishing the textile industry development Plan (2016-2020)). September 28. http://www.miit.gov.cn/n1146295/n1652858/n1652930/n3757019/c5267251/content.html. Accessed: September 30, 2016.

6 | Jost Wübbeke and Björn Conrad (2015). "'Industrie 4.0': Will German Technology Help China Catch Up with the West?" MERICS China Monitor (23). April 4. http://www.merics.org/en/merics-analysis/analyseschina-monitor/china-monitor23. Accessed: November 17, 2016.

7 | Zhou, Ji 周济 and Zhu Gaofeng 朱高峰 (eds.) (2015). 制造强国战略研究：智能制造专题卷 (Research on the manufacturing power strategy: smart manufacturing volume), 56. Beijing: Dianzi gongye chubanshe.

8 | Stepan, Matthias and Lea Shih (2016). "These Are the Super-Rich People Shaping China." Fortune. March 3. http://fortune.com/2016/03/03/china-national-peoples-congress-alibaba/. Accessed: August 25, 2016.

9 | State Council 国务院 (2015). "国务院关于印发《中国制造2025》的通知" (Notice of the State Council on the publication of 'Made in China 2025'). May 8. http://www.miit.gov.cn/n11293472/n11293877/n16553775/n16553792/16594486.html. Accessed: May 24, 2016.

10 | Expert Commission for the Construction of a Manufacturing Superpower [国家制造强国建设战略咨 询委员会] (2015). "《中国制造2025》重点领域技术路线图" ('Made in China 2025' key area technology roadmap). October. http://www.cae.cn/cae/html/files/2015-10/29/20151029105822561730637.pdf. Accessed: May 24, 2016; MIIT [Ministry of Industry and Information Technology] 工业和信息化部 (2015): "《中国制造2025》解读之：推动节能与新能源汽车发展" (Interpretation of 'Made in China 2025': Promoting the development of clean and new energy vehicles). www.gov.cn/zhuanti/2016-05/12/content_5072762.htm. Accessed: May 24, 2016.

11 | Communication with industry specialists.

12 | Giesen, Christoph and Thomas Fromm (2016): "Deutsche Autohersteller sind entsetzt über chinesische Elektroquote (German carmakers are shocked by Chinese quota for electric vehicles) http://www.sueddeutsche.de/wirtschaft/e-autos-deutsche-automobilhersteller-sind-entsetzt-ueberchinesische-elekroquote-1.3228492-2. Accessed: November 1, 2016.

13 | MERICS research of articles contained in Wanfang database (www.wanfangdata.com.cn).

14 | Liaoning and Guangdong for instance pay in 1 billion CNY each. MOF [Ministry of Finance] 财政部 (2016). "我国设立先进制造业投资基金" (China sets up the advanced manufacturing investment fund). July 15. http://www.mof.gov.cn/zhengwuxinxi/caizhengxinwen/201607/t20160715_2358336.htm). Accessed: July 22, 2016.

15 | BMWi [Bundesministerium für Wirtschaft und Energie] (2015). "Industrie 4.0: Digitalisierung der Wirtschaft." June 15. http://www.bmwi.de/DE/Themen/Industrie/industrie-4-0.html. Accessed: August 2, 2016; BMBF [Bundesministerium für Bildung und Forschung] (2016). "Zukunftsprojekt Industrie 4.0." September 2. https://www.bmbf.de/de/zukunftsprojekt-industrie-4-0-848.html. Accessed: August 2, 2016.

16 | Hong Kong Stock Exchange (2016). "BYD company ltd. – Announcement - completion of the additional A shares issue." July 21. http://www.hkexnews.hk/listedco/listconews/sehk/2016/0721/LTN20160721879.pdf. Accessed: September 22, 2016; Cninfo 巨潮资讯网 (2016). "上海新时达电气股份有限公司关于子公司股权划转并增资的公告" (Announcement of Shanghai Stepelectric concerning a subsidiary's equity share transfer and capital increase). May 26. http://www.cninfo.com.cn/finalpage/2016-05-26/1202338525.PDF. Accessed: September 22, 2016.

17 | Xinhuanet 新华网 (2016). "工信部批复宁波为首个《中国制造2025》试点示范城市" [The MIIT approves Ningbo as the first pilot city for 'Made in China 2025']. August 19. http://news.xinhuanet.com/city/2016-08/19/c_129240843.htm. Accessed: July 20, 2016; Cnstock 中国 证券网 (2016). "珠江西岸六市一区创建中国制造2025 试点示范城市群获批" (6 cities on the West coast of the Perl River Delta were established as Made in China 2025 pilot cities). September 30. http://news.cnstock.com/news/sns_bwkx/201609/3913804.htm. Accessed: October 6, 2016.

18 | Most of the local funding commitments apply to the period 2015-2017. Some have an extended period until 2020. The actual quantity of funds for smart manufacturing is presumably many times higher as most cities and provinces do not disclose the amount of funding and our analysis was confined to industrial robots alone.

19 | Personal communication with Southern Chinese smart manufacturing consultant.
20 | Feng, Qingyan 冯庆艳 (2016). "机器人补贴乱象调查地方"大跃进"拉响过热警报" (Investigation of subsidy chaos for robots: the local "Great Leap Forward" raises alarm. EEO 经济观察网. April, 30. http://www.eeo.com.cn/2016/0430/285698.shtml. Accessed: July 11, 2016.
21 | Xinhuanet 新华网 (2015). "工信部：最担心 '中国制造2025'再现重复建设" (MIIT: biggest concern for 'Made in China 2025' are reappearance of duplicate constructions). December 28. http://www.nmg.xinhuanet.com/xwzx/kjww/2015-12/28/c_1117602798.htm. Accessed: July 11, 2016.
22 | Prodhan, Georgina and Susan Fenton (2016). "Growth in demand for industrial robots halves as Chinese carmakers cut back." Reuters. September 29. http://www.reuters.com/article/us-robots-reportidUSKCN11Z1I2. Accessed: October 6, 2016.
23 | ZDNet 至项网 (2015). "若中国制造业升级 '有术无道' 那意义何在?" (What is the sense of industrial upgrading in China if it is based on "technology without principles". December 31. http://cio.zdnet.com.cn/cio/2015/1231/3070630.shtml. Accessed: July 11, 2016.
24 | Klorer, Elena and Matthias Stepan (2015). "Off target: China's vocational education and training system threatens the country's rise to industrial superpower status." MERICS China Monitor (24). October 2. http://www.merics.org/fileadmin/templates/download/china-monitor/China_Monitor_No_24_EN.pdf. Accessed: June 8, 2016.
25 | Zenglein, Max J. (2016). "China's overrated service sector: Missing dynamics threaten growth target." MERICS China Monitor (35). October 13. http://www.merics.org/en/merics-analysis/analyseschina-monitor/merics-china-monitor-no-35. Accessed: November 16, 2016.
26 | China Business Net 中国经济网 (2016). "富士康否认大量裁员但称机器人工人是未来" (Foxconn disclaims that a great amount of the work staff will be replaced by robots). June 6. http://www.ce.cn/cysc/zgjd/kx/201606/06/t20160606_12552239.shtml. Accessed: June 6, 2016; Guo, Rongcun 郭荣村 (2014). "海尔裁员上万背后：家电业机器人总动员自动化挑战 '中国制造'" (After Haier cut its workforce by over 10.000: automation in home appliances industry challenges 'Made in China').National Business Daily 每经网. June 24. http://www.nbd.com.cn/articles/2014-06-24/843550.html. Accessed: June 8, 2016.
27 | Zhang, Xiangmu 张相木 (2016). "智能制造试点示范专项行动" (Special action of smart manufacturing pilots). In: 国家制造强国建设战略咨询委员会 (Expert Commission for the Construction of a Manufacturing Superpower) and 中国工程院战略咨询中心 (Strategy centre of the Chinese Academy of Engineering) (eds.). 智能制造 (Smart manufacturing), 239-287. Beijing: Dianzi gongye chubanshe.
28 | Haier 海尔 (2013). "青岛海尔股份有限公司 600690 2012年年度报告" (Qingdao Haier joint-stock limited company 600690 2012 annual report). March 19. http://www.haier.net/cn/investor_relations/stock_a/finance_reports/201304/P020130411619658475178.pdf. Accessed: July 11, 2016; Haier 海尔 (2016). "青岛海尔股份有限公司 600690 2015年年度报告" (Qingdao Haier joint-stock limited company 600690 2015 annual report). April 28. http://static.sse.com.cn/disclosure/listedinfo/announcement/c/2016-04-29/600690_2015_n.pdf. Accessed: July 11, 2016.
29 | China business information net 中商情报网 (2015). "2015 中国工业机器人需求量状况分析" (2015 analysis of Chinas demand for industrial robots). April 16. http://www.askci.com/news/chanye/2015/04/16/1625133ox9.shtml. Accessed: May 18, 2016; Zhou, Ji 周济 and Zhu Gaofeng 高峰(eds.) (2015). 制造强国-战略研究：智能制造专题卷 (Research on the manufacturing power strategy: smart manufacturing volume), 56. Beijing: Dianzi gongye chubanshe.
30 | Su, Li 苏力 (2016). "广东产机器人迎来产品创新升级潮 产量年增4000 台" (Guangdong's robot production welcomes upsurge in product innovation level- within a year output increases by 4000 units). 人民网 (People's Daily Online). June 29. http://it.people.com.cn/n1/2016/0629/c1009-28508566.html. Accessed: July 11, 2016.
31 | World of finance net 金融界网站 (2015). "三一集团总裁唐修国：学德国工业4.0 光靠钱买不来" (Chairman of Sany Group Tang Xiuguo: it requires more than acquisitions to master Germany's Industry 4.0). November 19. http://finance.jrj.com.cn/people/2015/11/19161520102319.shtml. Accessed: June 27, 2016.
32 | Communication with manufacturer in Southern China.
33 | MOST [Ministry of Science and Technology] 科学技术部 (2013). "国家高技术研究发展计划（863 计 划）、国家科技支撑计划制造领域2014 年度备选项目征集指南" (State High-tech development plan (863 programme) Guidebook for the recruitment process for the 2014 projects of China's science and technology support programme in the field of manufacturing). April 16. http://www.most.gov.cn/tztg/201304/t20130416_100885.htm. Accessed: May 17, 2016; NMP [National Science and technology Major Project] 国家科技重大专项 (2009-2016). "高档数控机床与基础制造装备" (Advanced digital control machines and fundamental manufacturing equipment). http://www.nmp.gov.cn/gzxgz/skjc/. Accessed: May 17, 2016.
34 | SAT [State Administration of Taxation] 税务总部 (2011). "关于软件产品增值税政策的通知" (Notification concerning the VAT policy for software products). October 13. http://www.chinatax.gov.cn/n810341/n810765/n812156/n812464/c1186045/content.html. Accessed: August 24, 2016.
35 | The search strategy included the combination of the following technologies and keywords: smart sensors, RFID, data security and safety, wireless communication networks, additive manufacturing, programmable logical controller, embedded systems, cyber-physical systems, machine-to-machine communication and cloud computing.
36 | Hanemann, Thilo and Mikko Huotari (2016). "A new record year for Chinese outbound investment in Europe." MERICS and Rhodium Group (eds.). February. https://www.merics.org/de/merics-analysen/merics-studien/a-new-record-year-for-chinese-outbound-investment-in-europe/. Accessed: July 26, 2016.
37 | Xia, Xutian 夏旭田, He Changjuan 何长涓 and Zhang Fei 张飞 (2016). "国产机器人市场份额仅8% 自主品牌如何突围？" (Chinese robots have only 8% market share - how can independent brands break out of the enclosure?). 21st century economics report 21 世纪经济报道. July 09. http://m.21jingji.com/article/20160709/af13b6096fb6eb39cc48ad529db467a9.html. Accessed: July 26, 2016.

38 | People's Daily Online 人民网 (2016). "广东将加大机器人采购补贴 重点扶持15 家龙头企业" (Guangdong plans to increase subsidies for robot procurements with main focus on the 15 leading enterprises). January 26. http://gd.people.com.cn/n2/2016/0126/c123932-27633460.html. Accessed: July 28, 2016.

39 | Xia, Xutian 夏旭田, He Changjuan 何长涓 and Zhang Fei 张飞 (2016). "国产机器人市场份额仅8% 自主品牌如何突围？" (Chinese robots have only 8% market share - how can independent brands break out of the enclosure?). 21st century economics report 21 世纪经济报道. July 09. http://m.21jingji.com/article/20160709/af13b6096fb6eb39cc48ad529db467a9.html. Accessed: July 28, 2016.

40 | This figure is based on the industrial output targets of 25 parks. For the other parks, the figures are not available.

41 | Sun, Hua 孙华 (2016). "机器人市场有望达2000 亿元 规模利好细分行业龙头" (robot market promises to reach 200 billion CNY – scope favourable for market leaders of subdivisions). Sina Finance 新 浪财经. April 7. http://finance.sina.com.cn/roll/2016-04-07/doc-ifxrckae7567552.shtml. Accessed: August 8, 2016; China News 中国新闻网 (2016). "中国机器人市场未来10 年将达6000 亿元" (Chinese robotics market to reach 600 billion CNY within the next 10 years). April 09. http://www.chinanews.com/cj/2016/04-09/7828753.shtml. Accessed: August 8, 2016.

42 | CCID [China Center for Information Industry Development] 赛迪工业和信息研究院 (2016). "2015-2016 年中国工业软件市场研究年度报告" (2015-2016 annual industrial software market research report). March 10. http://www.ccidreport.com/report/content/5/201603/731278.html. Accessed: October 27, 2016.

43 | Personal communication with industry expert.

44 | Yonyou 用友(2016). "用友宣布进入3.0 时期，全面提供 '企业互联网服务'" (Yonyou announces entering phase 3.0, now providing comprehensive "company internet services"). August 13. http://subject.yonyou.com/zt/20160815/index.html. Accessed: August 15, 2016; Yonyou 用友(2016). "服务企业互 联网化打造社会化商业平台" (Upgrading enterprise internet services – creating a platform for social business). July 6. http://ftps.zdnet.com.cn/files/3/25208.pdf. Accessed: August 15, 2016; Xie, Shicheng 谢 世诚 (2016). "用友3.0 战略发布，图谋万家企业的互联网服务" (Yonyou announces strategy 3.0, internet services for 10.000 enterprises planned). August 15. http://www.doit.com.cn/p/253278.html. Accessed: August 16, 2016. 45 CCID [China Center for Information Industry Development] 赛迪工业和信息研究院 (2016). "智能制造 和工业软件发展白皮书" (Smart manufacturing and industrial software development whitebook). April 2016. http://www.ccidthinktank.com/uploads/soft/150421/ZHINENGZHIZAO.pdf. Accessed: October 27, 2016.

46 | KPMG (2014). "People's Republic of China Tax Profile." August. https://home.kpmg.com/content/dam/kpmg/pdf/2015/03/china-tax-profile-2014.pdf. Accessed: August 15, 2016; Chinadaily 中国日 报 (2015). "Preferential Policies for Foreign Investment in Software Industry." January 30. http://www.chinadaily.com.cn/m/jiangsu/wuxi/2015-01/30/content_19452536.htm. Accessed: August 15, 2016; MOF [Ministry of Finance] 财政无, shuiwu zongbu 税务总部, fazhan gaigewei 发展改革委, gongye he xinxihuabu 工业和信息化部 (2016). "关于软件和集成电路产业企业所得税优惠政策有关问题 的通知" (Notice on questions relating to the favourable income tax policy for enterprises of the software and IC industries). May 4. http://www.chinatax.gov.cn/n810341/n810755/c2128416/content.html. Accessed: July 28, 2016; Beijing Municipal Commission of Economy and Information Technology 北京 市经济和信息化委员会 (2016). "软件企业享受所得税优惠政策通知解读及企业备案资料说明" (Decoding of the notice on the preferential income tax reform for software companies and explanation of filing requirements). June 29. http://www.bjeit.gov.cn/docs/2016-06/20160614163837519005.pdf. Accessed: July 28, 2016; The Beijing News 新京报 (2014). "政府补贴上市公司资金连年暴增" (Government subsidies for listed companies increased over the last couple of years). August 5. http://epaper.bjnews.com.cn/html/2014-08/05/content_527679.htm?div=0. Accessed: July 28, 2016; Zhou, Yong 周勇 (2013). "用友软件上半年靠补贴扭亏" (The first half of 2013 Yonyou depended on subsidies to reverse loss). Sootoo 速途网. August 13. http://www.sootoo.com/content/440276.shtml. Accessed: August 10, 2016.

47 | Cnstock 中国证券网 (2016). "ERP 国产化政策支持态度明确，静待细则给予更大催化" (ERP localisation policy supports clear-cut manner, static rules and regulations show a bigger reaction). August 4. http://stock.10jqka.com.cn/20160804/c592160673.shtml. Accessed: August 10, 2016; Kingdee 金蝶 (2016). "金蝶云ERP 亮相制造业与互联网融合峰会" (Kingdee cloud ERP presented at the manufacturing and internet integration summit meeting) http://www.028kingdee.net/news/1574.html. Accessed: August 9, 2016; Gongkong 中国工控网 (2016). "工信部开展国产工业软件展示对接活动" (MIIT launches Chinese industry and software enterprises exchange event). January 26. http://www.gongkong.com/news/201601/337623.html. Accessed: August 9, 2016; Deng, Wenlong 邓 文龙 (2016). "'2016 年度国产工业软件优秀解决方案展示对接系列活动' 举办福建专场" ("2016 event series for Chinese industry and software enterprises to exchange outstanding software solutions" held in Fujian). CINN 中国工业新闻网. January 22. http://www.cinn.cn/quy/jizhezhan/fujian/352288.shtml. Accessed: August 10, 2016.

48 | China Entrepreneur Club 中国企业家俱乐部 (2016). "用友软件王文京：政府应继续积极发展软件产 业" (Yonyou's Wang Wenjing: the government should continue to vigorously develop the software industry). May 10. http://www.daonong.com/html/dongtai/qiye/wangwenjing/20160510/59304.html. Accessed: May 16, 2016; Mingren Bokewang 名人博客网 (2016). "我国软件产业呼吁政府采购" (China's software industry calls for government procurement). April 18. http://blog.qicvbjmn.net/yrzb/1034.html. Accessed: May 16, 2016.

49 | Hapi Research 海比研究 and Division for Finance and Business Management Software of the China Software Industry Association 中国软件行业协会财务及企业管理软件分会 (2014). "大型企业信息系统 的国产化路径" (Information system localisation path for large-scale enterprises). June. http://nc.yonyou.com/nc/download/% E5%A4%A7%E5%9E%8B%E4%BC%81%E4%B8%9A%E4%BF%A1%E6%81%AF%E7%B3%BB%E7%BB%9F%E7%9A%84%E5%9B%BD%E4%BA%A7%E5%8C%96%E8%B7%AF%E5%BE%84.pdf. Accessed: May 16, 2016.

50 | Qianzhan 前瞻产业研究院 (2016). "增彩制造 '增值' 可期3D 打印产业快速发展" (The additive manufacturing industry increases its value - the 3D printing industry develops quickly). http://wenku.baidu.com/view/4463a1f7f18583d04864593f.html. Accessed: June 22, 2016.

51 | Ang, Francis Eduard (2015). "3D printing industry expected to boom near future." Yibada. November 4. http://en.yibada.com/articles/81234/20151104/3D printing-technology-expected-boom-near-future. htm. Accessed: June 21, 2016.

52 | Luxresearch (2014). "'3D printed in China' – China bids for leadership in emerging 3D printing technology." September 30. http://www.luxresearchinc.com/news-and-events/press-releases/read/3dprinted- china-%E2%80%93-china-bids-leadership-emerging-3D printing. Accessed: June 23, 2016.

53 | Ang, Francis Eduard (2015). "3D printing industry expected to boom near future." Yibada. November 4. http://en.yibada.com/articles/81234/20151104/3D printing-technology-expected-boom-near-future. htm. Accessed: June 21, 2016.

54 | Ipsos Business Consulting (2015). "Opportunities and challenges in China's 3D printing market." May. http://www.ipsosconsulting.com/pdf/White-Paper-Opportunities-And-Challenges-In-China's-3D printing-Market.pdf. Accessed: June 14, 2016.

55 | Yan, Alice (2016). "Chinese builders use 3D printing technology to create Beijing villa." SCMP [South China Morning Post]. June 30. http://www.scmp.com/news/china/society/article/1983582/chinese-builders-use-3d-printing-technology-create-beijing-villa. Accessed: June 30, 2016.

56 | Yang, Kristine (2015). "Dawn of a new dimension." China Daily Europe. January 23. http://europe.chinadaily.com.cn/epaper/2015-01/23/content_19386186.htm. Accessed: June 14, 2016; Xinhuanet 新华网 (2015). "Premier urges stronger advanced manufacturing." August 23. http://news.xinhuanet.com/english/2015-08/23/c_134547113.htm. Accessed: June 14, 2016.

57 | MOST [Ministry of Science and Technology] 科学技术部 (2013). "国家高技术研究发展计划（863 计 划）、国家科技支撑计划制造领域2014 年度备选项目征集指南" (State High-tech development plan (863 programme) Guidebook for the recruitment process for the 2014 projects of China's science and technology support programme in the field of manufacturing). April 16. http://www.most.gov.cn/tztg/201304/t20130416_100885.htm. Accessed: July 7, 2016.

58 | MIIT [Ministry of Industry and Information Technology] 工业和信息部, fazhan he gaige weiyuanhui 发展和改革委员会, caizhengbu 财政部 (2015). "三部门联合印发《国家增彩制造产业发展推进计划》(2015-2016 年)" (3 departments jointly publish "the country's additive manufacturing industry promotion plan (2015-2016)). February 28. http://www.miit.gov.cn/n1146290/n4388791/c4215251/content.html. Accessed: July 7, 2016.

59 | Sohu 搜狐 (2016). "科技部重点项目：增材制造企业揽获2.3 亿投资" (MOST key project: additive manufacturing companies snatch 2.3 billion CNY investment). July 6. http://mt.sohu.com/20160706/n458002046.shtml. Accessed: July 8, 2016; Beijing Times 京华时报 (2013). "3D 打印入选863 计划 国家拨付4000 万研究资金" (3D printing included in the 863 programme, the country appropriates 40 million CNY research funds). April 27. http://www.nanjixiong.com/article-722-1.html. Accessed: July 8, 2016.

60 | Voxeljet (2015). "Voxeljet expandiert nach China und Indien." December 14. http://www.voxeljet.de/news-und-events/news/voxeljet-expandiert-nach-china-und-india/. Accessed: August 2, 2016; Molitch-Hou, Michael (2015). "Solidscape and Kangshuo Group open largest 3D printing service in China." 3D printing industry. July 23. http://3dprintingindustry.com/news/solidscape-and-kangshuogroup- open-largest-3D printing-service-in-china-54051/. Accessed: August 2, 2016.

61 | Krassenstein, Brian (2015). "Shining3D to spin off Regenovo bio-printing brand, enter 3D printing resin market." 3Dprint.com. May 21. https://3dprint.com/67183/shining3d-regenovo/. Accessed: July 19, 2016.

62 | Hunan Daily 湖南日报 (2015). "中国工业及3D 打印首次走出国门" (Chinese industrial 3D printers enter foreign markets for the first time). September 26. http://hnrb.voc.com.cn/hnrb_epaper/html/2015-09/26/content_1017328.htm?div=-1. Accessed: July 18, 2016.

63 | 3ders – 3D printing news (2015). "Collaboration of BASF, Farsoon and LSS results in high strength PA6 powder for SLS 3D printing." November 17. http://www.3ders.org/articles/20151117-basf-farsoonand-lss-results-in-high-strength-pa6-powder-for-sls-3D printing.html. Accessed: July 20, 2016.

64 | 3ders – 3D printing news (2014). "CTC Electronics heavily investing in China's largest 3D printer factory." September 28. http://www.3ders.org/articles/20140928-ctc-electronics-heavily-investing-inchina-largest-3d-printer-factory.html. Accessed: June 18, 2016.

65 | Grunewald, Scott J. (2016). "Zhuhai CTC Electronic's Walnut Line is China's first proprietary metal 3D printer." March 31. https://3dprint.com/127471/ctc-walnut-metal-3d-printer/. Accessed: July 18, 2016.

66 | Ruan, Runsheng 阮润生 (2015). "大基金将吸纳海外资本 积极推动国际并购" (The National IC Fund will accept capital from overseas to vigorously push for international M&As). Securities Times 证券时 报. September 18. http://epaper.stcn.com/paper/zqsb/html/epaper/index/content_733669.htm?fin. Accessed: July 28, 2016.

67 | Wang, Xiaohong 王晓红 (2016). "鼓励民企积极参与对外投资战略布局" (Encouraging private companies to actively participate in foreign investment strategies). Economic Daily 经济日报. September 1. http://www.ce.cn/xwzx/gnsz/gdxw/201609/01/t20160901_15465076.shtml. Accessed: September 2, 2016.

68 | David Evans (2016). "Government Fund Weekly New Roundup – SWFs Target Tech Startups." Sovereign Wealth Center. January 15. http://www.sovereignwealthcenter.com/Article/3521311/Government-Fund-Weekly-News-RoundupSWFs-Target-Tech-Startups.html#/.WC2IhfnhBPY. Accessed: November 17, 2016.

69 | St. Clair, Jeffrey (2006). "The Saga of Magnequench." Counterpunch. April 7. http://www.counterpunch.org/2006/04/07/the-saga-of-magnequench/. Accessed: September 2, 2016.

70 | Fahrion, Georg (2016). "Aixtron – Chinas Staatsstreich." Capital. October 24. http://www.capital.de/dasmagazin/aixtron-chinas-staatsstreich.html. Accessed: October 24, 2016; Meng, Baole 孟宝勒 and Jack Ewing (2016). "中国资本涌入欧洲尖端技术产业引发担忧" (Rush of Chinese investment in Europe's high-tech firms is raising eyebrows). The New York Times. September 18. http://www.nytimes.com/2016/09/17/business/dealbook/china-germany-takeover-merger-technology.html?_r=0. Accessed: September 20, 2016.

71 | U.S. Securities and Exchange Commission (2016). "Reasoned Statement of the management board and the supervisory board of Aixtron SE on the voluntary publiy takeover offer (cash offer) by Grand Chip Investment GmbH." August 4. https://www.sec.gov/Archives/edgar/data/1089496/000104746916014937/a2229459zex-99_a1.htm. Accessed: September 20, 2016.

72 | Meissner, Mirjam and Jost Wuebbeke (2016). "End of the road for international car makers in China? How digitisation will reshape the automobile market." MERICS China Monitor (31). April 19. https://www.merics.org/en/merics-analysis/analyseschina-monitor/end-of-the-road-for-internationalcar-makers-in-china.html. Accessed: September 21, 2016.

73 | Dickinson, Steve (2015). "Foreign SaaS in China: get off of my cloud." China Law Blog. April 14. http://www.chinalawblog.com/2015/04/foreign-saas-in-china-get-off-of-my-cloud.html. Accessed: August 23, 2016; MIIT [Ministry of Industry and Information Technology] 工业和信息化部 (2009). "电信业务经营许可管理办法" (Permitted management methods for businesses in the telecommunication industry). March 11. http://www.gov.cn/flfg/2009-03/11/content_1256595.htm. Accessed: August 23, 2016.

74 | Li, Yu (2014). "可信云服务认证标准和评估方法" (authentication standards and evaluation methods for trustworthy cloud services).idcquan.com 中国IDC . July. http://www.idcquan.com/Special/2014trucs/ppt/lw.pdf. Accessed: August 24, 2016; Data Center Alliance 数据中心联盟 (2015). "32 个云服务通过第三批可信云服务认证" (32 Cloud services got through the 3rd trustworthy cloud services authentication stage). January 29. http://www.dca.org.cn/content/100164.html. Accessed: August 24, 2016.

75 | Heilmann, Sebastian and Matthias Stepan (eds.) (2016). "China's core executive – Leadership styles and processes under Xi jinping." MERICS Paper on China (1). June. http://www.merics.org/en/merics-analysis/papers-on-china/chinas-core-executive-leadership-styles-structures-andprocesses-under-xi-jinping.html. Accessed: July 28, 2016; China Business Net 中国经济网 (2016). "'互联网+'时代 电子商务信用体系建设亟待加强" (In the era of 'internet+' the construction of an e-commerce credit system needs to be reinforced). February 29. http://www.ce.cn/cysc/tech/gd2012/201602/29/t20160229_9156705.shtml. Accessed: July 28, 2016.

76 | ZVEI [Zentralverband Elektrotechnik- und Elektroindustrie e.V.] (2015). "Industrie 4.0: Das Refrerenzarchitekturmodell Industrie 4.0 (RAMI 4.0)." April. http://www.zvei.org/Downloads/Automation/ZVEI-Faktenblatt-Industrie4_0-RAMI-4_0.pdfg. Accessed: August 9, 2016.

77 | IEC 62601:2015 and IEC PAS 62948:2015

78 | www.rolandberger.com/publications/publication_pdf/roland_berger_tab_industry_4_0_20140403.pdf

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