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Report on China: technological capacities and key policy measures

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Introduction

The objective of the international country reports is to explore the technology and policy landscape of selected non-European countries. Country performance in advanced technologies is presented based on patent, trade and investment data. The reports provide also a concise and informative review of policies relevant for advanced technology development and deployment.

The starting point of this analysis has been sixteen advanced technologies that are a priority for European industrial policy and that enable process, product and service innovation throughout the economy and hence foster industrial modernisation.

Advanced technologies are defined as recent or future technologies that are expected to substantially alter the business and social environment and include *Advanced Materials, Advanced Manufacturing, Artificial Intelligence, Augmented and Virtual Reality, Big Data, Blockchain, Cloud Technologies, Connectivity, Industrial Biotechnology, the Internet of Things, Micro and Nanoelectronics, Mobility, Nanotechnology, Photonics, Robotics and Security*. The full methodology behind the data calculations is available on the ATI website: https://ati.ec.europa.eu.

The report is structured as the following:

The first section outlines the capacities of China in terms of technology generation (patent applications), followed by an analysis of international competitiveness in technology-based products (export shares) and, eventually, entrepreneurial dynamism (venture capital activities and investments in tech firms).

The second section analyses the main policy strategy of China in support of advanced technologies and provides an overview of some of the key policy initiatives and policy measures in the field.

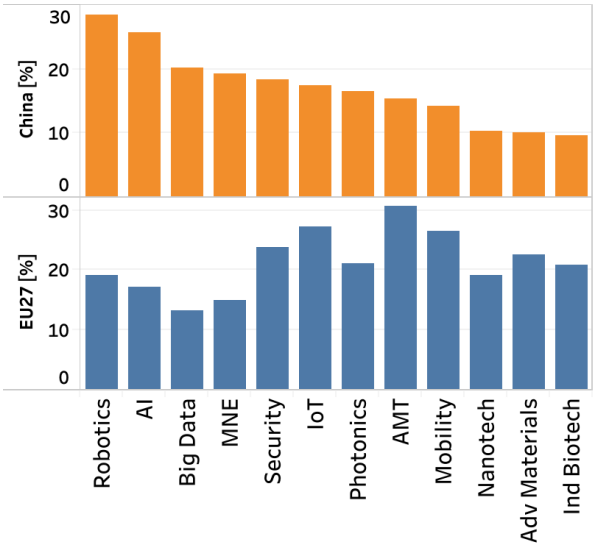
Section 1

1. Activities and capacities in advanced technologies

1.1 Patent applications

Over the past decade the technological performance of China has improved rapidly. An analysis of China's share in worldwide transnational patent applications helps to assess and benchmark its technological performance. Figure 1 provides an overview of the Chinese share of worldwide transnational patent applications in advanced technologies compared to that of the EU27's Member States in 2017[1].

Figure 1: Share in global transnational patent applications in advanced technologies (2017)[2]

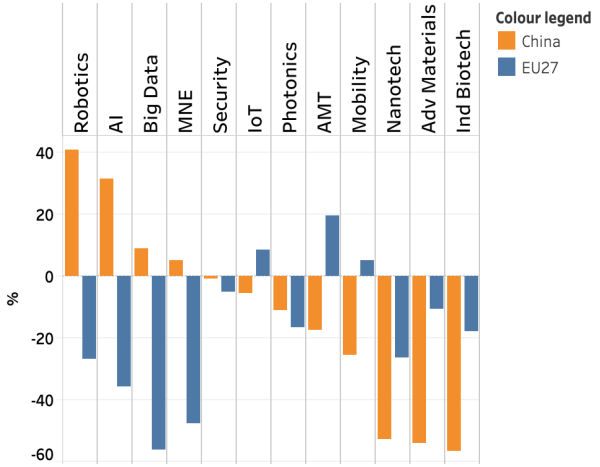


Source: Fraunhofer ISI, based on EPO PATSTAT, tableau

As seen in Figure 1, the EU27 continues to hold a higher share of global patent applications than China in most advanced technologies. However, China has come close to Europe in Photonics, Security as well as to some degree the Internet of Things and Nanotechnology. China's share in global patenting had already clearly exceeded the one of Europe in Micro- and nanoelectronics (MNE), Robotics, Artificial Intelligence and Big Data.

The analysis of the RPA-index[3] as visualised in Figure 2 demonstrates China's relative technological specialisation in all twelve advanced technologies in comparison to EU27. It confirms China's technological focus on information technologies (see Figure 1) with outstanding specialisation in Robotics and Artificial Intelligence as well as - to a lesser extent - Big Data and Micro- and nanoelectronics. The EU27 displays, however, a negative specialisation in all four of these fields.

Figure 2: Technological Specialisation RPA-Index of China and EU27 (2017)



Source: Fraunhofer ISI, based on EPO PATSTAT, tableau

1.2 International competitiveness

Trade measures are a common indicator of global competitiveness, as they document the attractiveness of a country's products beyond the home market. Total exports provide evidence about a country's role as a producer, and trade balance captures its sovereignty in certain areas of production.

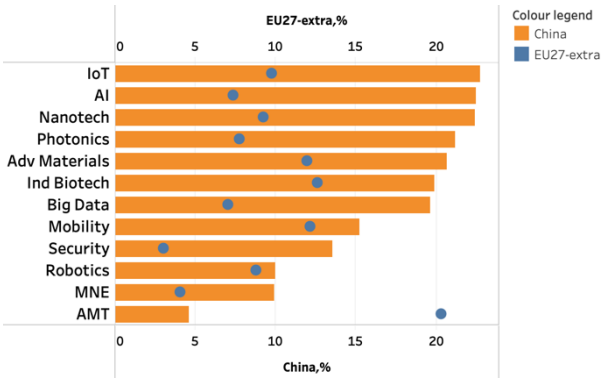
Figure 3 displays the share of global technological exports in 2016. It clearly demonstrates that China exports more than the European Union in all fields of advanced technologies except for Advanced Manufacturing (AMT).

[1] The patent analysis reflects the owner (applicant) of the technology, since patents have been localised based on the location of their legal owner.

[2] The diagrams in this report have been prepared with the software tableau.

[3] The RPA-Index illustrates the relative specialisation on a scale from -100 to +100, putting the share of a specific field in national applications in relation to the global average share.

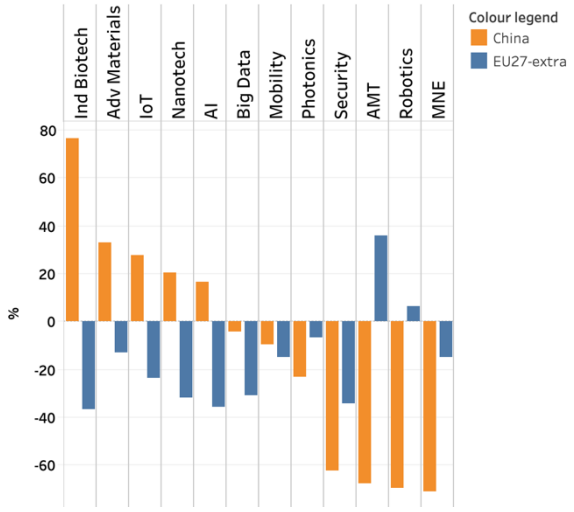
Figure 3: Export share in world total (2016)



Source : Fraunhofer ISI, based on UN COMTRADE
Note: "EU27-extra" refers to exports to non-EU countries, i.e. competitiveness-based exports outside the single market The view is filtered on China, which ranges from 4.6-22.8%

Figure 4 visualises the trade balance[4] in relation to the total trade volume of China and the EU27 countries in 2016.

Figure 4: Trade balance in relation to overall trade volume (exports - imports) (2016)



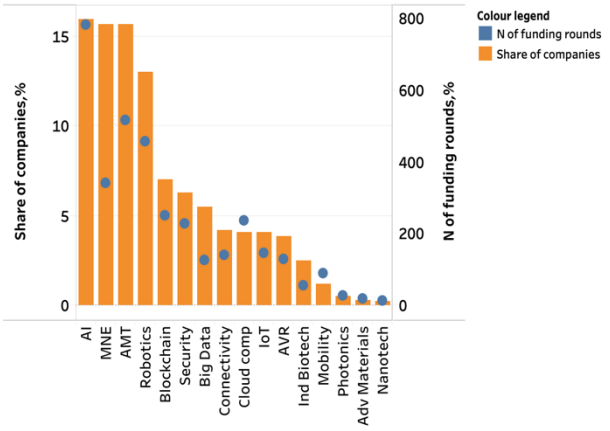
Source: Fraunhofer ISI, based on UN COMTRADE
Note: "EU27-extra" refers to exports to non-EU countries, i.e. competitiveness-based exports outside the single market

China displayed a large relative trade surplus in 2016 in Industrial Biotechnology (76%), Advanced Materials (33%) and IoT (28%). The analysis shows, however, a rather notable trade deficit in terms of total trade volume in Micro and nanoelectronics (over 60%), Advanced Manufacturing, Security and Mobility. The European Union had significant relative trade deficits almost in all fields related to advanced technologies - with the exception of Advanced Manufacturing Technology and Robotics.

1.3 Investment activities

The following figures analyse private and venture capital (VC) investment in advanced technologies in China. Figure 5 illustrates the number of investment deals in advanced technologies and the share of investment-backed firms in China based on Crunchbase[5] data. The results have to be interpreted with caution since the data from Chinese startups and scaleups are limited. The analysis suggests that the relative number of investment-backed firms was the highest in Artificial Intelligence, Micro- and nanoelectronics, Security and Advanced Manufacturing.

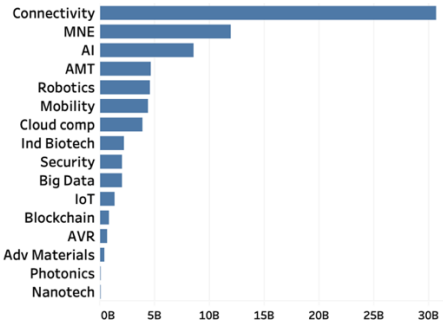
Figure 5: The number of funding rounds and share relative to the number of companies in China (2019)



Source: Technopolis Group based on Crunchbase

Figure 6 depicts the total amount of VC funding invested in Chinese startups and scaleups active in the sixteen advanced technologies in the last decade.

Figure 6: Total last round investments in advanced technologies, in € 2009-2019



Source: Technopolis Group based on Crunchbase

The results indicate that Chinese firms received the highest amount of investment in Connectivity and Micro- and nanoelectronics, followed by Artificial Intelligence.

[4] Exports - Imports

[5] Private equity, venture capital investment and related innovative startup creation have been explored based on the dataset available in Crunchbase. Crunchbase provides information on venture capital backed innovative companies.

Section 2

2. Key actors, policy and governance framework

2.1 Overview and policy context

Policy strategy		
Title	*Year*	
13th Five-Year Plan	2016-2020	
Made in China 2025 (MIC25)	2015-ongoing	
Internet Plus	2015-ongoing	
Belt and Road Initiative (BRI)	2013-ongoing	
Policy measures		
Title	*Year*	*Budget*
Strategic Pioneering Programme on Nanotechnology (CAS)	2012-ongoing	€129 m (five years)
Cloud Computing Development 3-year Action Plan (MIIT)	2017-2019	part of €13 bn plan*
New Generation of Artificial Intelligence Development Plan	2017-ongoing	€130-410 m for R&D**
Intelligent Manufacturing Development Plan	2016-2020	part of €380 bn plan***
Additive Manufacturing Industry Development Action Plan	2017-2020	
* Agreement of NDRC and China Development Bank, cf. Reuters, 2018 **public expenditures 2018 by NSFC, in National Key Projects and Megaprojects, cf. IDA, 2020 ***total volume of public industrial investment funds under MIC 2025, estimate, cf. MERICS, 2019		

Source: authors

The relevance of the digital economy in China has grown rapidly in the last years and it is valued at approximately 30% of GDP.[6] The level of digitalisation in the China's economy is particularly high in e-commerce and financial technology.[7] The annual growth of China's e-commerce sector increased from 5.5% in 2009 to almost 11% in 2017. New business models in the Chinese import market enable cross-border e-commerce for consumers, which is why China expects to have over 200 million consumers in that market by 2020.[8] According to the European Commission, China has the most active digital investment and startup ecosystems in the world.[9] According to the Hurun Global Unicorn list, 206 of worldwide 494 unicorn companies (startups valued at over $1 bn) are Chinese.[10]

Very clearly, the findings presented in section one illustrated China's positioning as a nation and economy in dynamic catch-up. Since at least the mid-2010s this catch-up is no longer merely economical or imitative, but also concerns genuine, independent technological and innovation capacities.

While the above trade analysis confirms China's established role as the world's key producer of advanced technology related goods (that still imports various central components) patent and investment analyses document that own capacities are rapidly growing in all fields, most prominently those related to digital technologies.

Since the early 2000s and, more vigorously, the 2010s, China's policymakers have put a strong emphasis on these fields, realising that it would be hard for their firms to catch up with US or European incumbents in some of the established key enabling technologies. At the same time they recognised early that the digital revolution has a pervasive character. Gaining a head start in the areas most relevant to China would enable the country to catch-up on a broader basis as well.

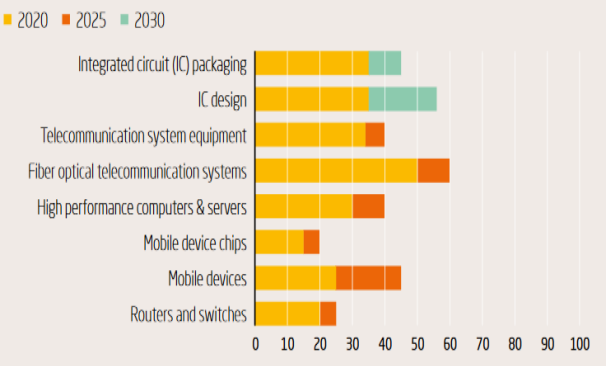
Accordingly, the initiatives presented below reflect the coordinated attempt to orchestrate and support the increasingly dynamic catch-up of a nation moving from follower to leader, with a clear focus on the digital technologies. That said, China's policymakers are aware that balanced industrial development will require

[6] Salman 2019, p. 34.
[7] Zhang and Chen, p. 2.
[8] Deloitte Research 2019, p. 7.
[9] European Commission 2020.
[10] Hurun Research Institute 2019.

complementary capabilities as well, motivating e.g. parallel investments in nanotechnology and advanced manufacturing. As common in China, many of the presented initiatives constitute frameworks and strategies with more than one level of implementation, hence, it is usually not possible to specify an overall budget.

Figure 7 summarises China's targets for its global market share in information and communication technologies for 2020, 2025 and 2030 according to the technology roadmap (2015, 2017) of the National Manufacturing Strategy Advisory Committee (NMSAC).

Figure 7: China's targets for global market share in IT services and products (in percent)



Source: Shi-Kupfer and Ohlberg 2019, p.18

2.2 Government policies towards technology development and adoption

China is seeking global digital and technological leadership and to reach this it has launched several policy actions and strategies. This ambition is driven by the government as well as economic actors. A variety of digitalisation goals drive the policy and macro-economic planning in China.

Figure 8 (next page) gives an overview about some Chinese policy initiatives at different levels from the 2000s until 2018.

China issued the strategy and industrial policy plan **'Made in China 2025'** (MIC 2025) in May 2015. The strategy aims to strengthen and upgrade the Chinese manufacturing industry, turning China into a manufacturing superpower that is able to drive innovation, set standards and control global supply chains. The initiative can be seen as an answer to the slowing growth and the expressed need to establish a new model of growth. It consists of different goals and sub-plans concerning ten key priority industries: IT, robotics, green energy and green vehicles, aerospace equipment, ocean engineering and high tech ships, railway equipment, power equipment, new materials, biomedicine and medical devices and agriculture machinery. Almost all provinces and municipalities (28 out of 31) released individual implementation plans for MIC 2025, oriented towards the national plan.

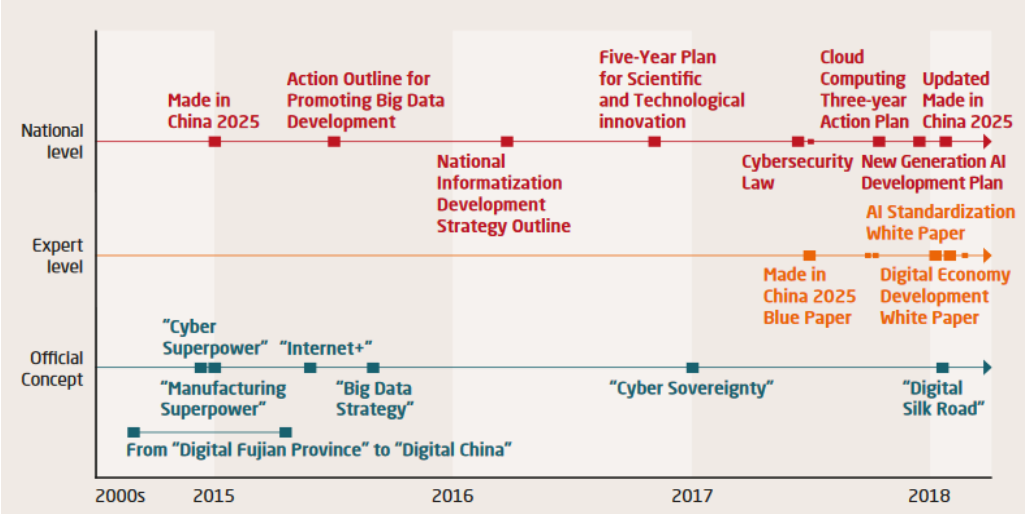
Policymakers in China noticed the important role of the digital economy and included specific goals and measurements in the 13th five-year plan (2016-2020). The plan expresses the need to firmly establish and put into practice a new philosophy of innovative, coordinated, green, open, and shared development. Focusing on digitalisation, the 13th five-year plan contains initiatives to upgrade the digital infrastructure of the country, to strengthen capabilities with respect to high-speed transmission, cross-border cable infrastructure, wireless networks (4G/5G) and the development of an 'online silk road' with the Arab countries. A focus on information technology breakthroughs is set on various technologies, e.g. big data, cloud computing and artificial intelligence technologies.

In the area of new information network technologies, the 5-year plan aims to advance research in key technologies for 5G networks and to develop commercial applications of the 5th generation technology. In order to achieve this 5G development, China pursues a central strategy in which the government intervenes directly in the economy to ensure production efficiency, create synergies in the domestic market and to protect it from foreign competition. In 2013 the IMT-2020 (5G) Promotion Group was established by three Chinese ministries with the aim of coordinating the leading companies, universities, research institutes and government groups in the research and commercialisation of 5G technologies by the end of 2020.

The 13th five-year plan lists the following Information Technology Projects:

- The National Broadband Agenda,
- Promoting application of the Internet of Things,
- Cloud computing innovation and development,

Figure 8: Overview of key policy initiatives in China.



Source: Shi-Kupfer and Ohlberg 2019, p.18

- "Internet Plus",
- Big Data applications,
- A more IT-based government,
- E-commerce and
- Cybersecurity.

President Xi Jinping proposed the 'Belt and Road Initiative' (BRI) in 2013. The initiative supports trade, investment and the building of infrastructure with the goal of strengthening the links (land and maritime) between China and major countries in Eurasia and Africa.

The project **'Digital Silk Road'** is a subset of the BRI. Since 2013, over €15 bn was invested into its projects by Chinese entities. Table 1 provides an overview of the scope of various projects in the context of the Digital Silk Road.

The action plan **'Internet Plus'** aims at promoting the internet throughout all economic and social fields. The plan is supposed to differentiate China from other countries.[11] It shows efforts to integrate digital services and technologies, such as cloud computing and the Internet of Things into the manufacturing industries, to develop a 'new mode of collaborative manufacturing based on the internet'. Moreover, it promotes the integrated development of internet services with relation to agriculture products, energy, and the finance sector to support the growth of e-commerce and to create positive, synergic dynamics in the internet industry.[12] 'Internet Plus' consists of five key actions[13]:

- Entrepreneurship and innovation
- Collaborative manufacturing
- Modern agriculture
- Intelligent energy
- Inclusive finance

Table 1: Projects and examples of the Digital Silk Road

Project	Examples
Developing major infrastructure projects	Fibre-optic cables across the Arctic Circle; Broadening coverage of Beidou GPS system; Setting up data centres
Promoting Chinese Standards	AI standards
Engaging in research collaborations	Belt and Road Programme on Big Earth data collaboration; Partnership between the EU and China on 5G; Technology transfer centres
Raising China's global 'discursive power'	Promoting concepts like 'internet sovereignty'; Promoting changes to global internet governance

Source: Shi-Kupfer and Ohlberg 2019, p.1

[11] Godement et al. 2018.
[12] State Council 2015.
[13] State Council 2015.

2.3 Government initiatives to foster specific advanced technologies

Artificial Intelligence

Chinese policymakers state that the rapid development of artificial intelligence will profoundly change human social life and the world.[14] The mastering of artificial intelligence is seen as a major strategic opportunity, which is why the **'New Generation of Artificial Intelligence Development Plan'** was issued in 2017. The country hopes to build up first-mover advantage in the AI development, since technology gaps are more fluid in emerging technologies. The plan concludes that China has a good basis for the development of AI technology and has made important breakthroughs in applied fields like voice recognition, visual recognition and adaptive autonomous learning but still lacks major original results concerning basic theories, the core algorithm and key equipment like high-end chips.[15] China intends to set up over 50 AI-related academic and research institutes by 2020.[16]

Its strategic goals are divided into three steps[17]:

- Keeping up the technology and application of AI with other advanced nations by 2020.
- Achieving important developments in AI basic research and processing to world leadership in some technology parts and its application by 2025.
- Becoming the AI innovation centre by 2030 with the world leadership in AI theory, technology and its application with the broader goal of thereby strengthening China's economic powers overall.

Nanotechnology

China is heavily investing in the development of nanotechnology. Since 2006, various projects have been funded on topics like nanomaterials, nanomedicine or nanoenergy. The Ministry of Science and Technology (MOST) supports a majority of these projects. Three major programmes were funded by the National Natural Science Foundation of China with ¥200 m (€27 m[18]) in nanoscience, nanomanufacture and molecular assembly.[19]

In 2012 the **'Strategic Pioneering Programme on Nanotechnology'** was launched with a budget of approx. €129 m[20] (¥1 bn) over five years. The programme's focus is on applied nanotechnology research.[21]

The Chinese Academy of Sciences (CAS) set up the Centre for Excellence in Nanoscience in 2015. The purpose of this centre is to bring together talent, achieve successful breakthroughs and become an internationally successful organisation.[22] [23]

Cloud Computing

In 2017 the Ministry of Industry and Information Technology (MIIT) published the **'Cloud Computing Development Three-year Action Plan'** (2017-2019). The plan of developing a high-end and international cloud computing industry for China is set to pursue the 2015 strategies of promoting cloud computing and new business models in the IT industry.[24] The plan lists various objectives:

- Creating a strong basis for cloud computing by adapting policies regarding R&D, standardisation and industrial organisation.
- Pushing the industry developments by establishing pilot applications.
- Establishing a working cloud ecosystem by securing resources.
- Using upgraded network security technologies to guarantee safety.
- Helping local cloud computing organisations to expand to international markets.[25]

In 2018, the National Development and Reform Commission (NDRC) published an agreement with the China Development Bank to invest €13 bn into Cloud Computing, Big Data and Smart City Projects until 2023.[26]

Internet of Things (IoT)

The importance of the Internet of Things and its effect on the economy is globally recognised. China is committed to become the leader in IoT development, which is why the Chinese Premier Wen Jiabao made the IoT a key industry for China in 2009 already and announced major

[14] State Council 2017b, p. 1.
[15] State Council 2017b.
[16] Shi-Kupfer and Ohlberg 2019, p. 9.
[17] State Council 2017b, 5ff.
[18] The amount in Euro was calculated based on the ECB's official Euro foreign exchange reference rates for 2016.
[19] Qiu 2016, p. 148.
[20] The amount in Euro was calculated based on the ECB's official Euro foreign exchange reference rates for 2016.
[21] Qiu 2016, p. 149.
[22] NCNST 2020.
[23] Qiu 2016, p. 149.
[24] USITO 2017.
[25] USITO 2017.
[26] Reuters, 2018

investment plans.[27] [28] Since then, China has been fostering national research and development offering initiatives and financial support. Thus, the IoT-market experienced rapid growth: it was valued at approx. €128 bn in 2017 with a forecasted value of €220 bn[29] by 2020.[30]

The manufacturing sector is projected to experience the highest gains from the IoT in China. In an enhanced scenario, "the economic value from the IoT could jump from $196 bn (€180 bn) [31] to $736 bn (€677 bn) by 2030 - a 276% increase".[32] Accounting for almost 30% of GDP in 2018, manufacturing plays an important role in China's economy.[33]

Advanced Manufacturing

In 2016, the Chinese government released its **'Intelligent Manufacturing Development Plan'** (2016-2020). It demands further development in the areas of smart equipment and key technologies, standardisation, smart manufacturing tests and it promotes intelligent digital transformation. The plan aims at generating growth for the Chinese manufacturing sector with a focus on ten sectors, e.g. new generation information technology, aerospace and advanced rail.[34]

The **'Additive Manufacturing Industry Development Action Plan'** (2017-2020) is formulated as part of the strategic roadmap 'Made in China 2025.[35] The Chinese Ministry of Industry and Information Technology, in cooperation with eleven other agencies, released guidelines to strengthen and further develop the 3D printing sector in China. The Chinese government expects the 3D printing industry to keep up its annual growth rate of over 30% and its revenue to top approx. €2.56 bn[36] (¥20 bn) in 2020.[37]

A variety of specific objectives are listed in China's move to boost 3D printing[38]:

- The locally developed core technology reaches international levels: two or three Chinese companies will be competitive and accepted on international markets.
- Breakthroughs will be made in over 100 sorts of technological equipment, key devices and special materials.
- Over 100 pilot projects will be launched.
- The technology will have a broad utilisation in different areas, e.g. aviation, car manufacturing, education.

The MIIT pledges to increase its financial support for companies, promotes diverse financing models and financial leasing. The Ministry will encourage foreign organisations to base their R&D of 3D-printing technologies in China.[39]

[27] Chen et al. 2018, p. 2.
[28] APEC 2015, p. 8.
[29] The amount in Euro was calculated based on the ECB's official Euro foreign exchange reference rates for 2017.
[30] Chen et al. 2018, p. 2.
[31] The amount in Euro was calculated based on the ECB's official Euro foreign exchange reference rates for 12/2015.
[32] Accenture 2015, p. 8.
[33] World Bank 2020.
[34] State Council 2016.
[35] Haria 2017.
[36] The amount in Euro was calculated based on the ECB's official Euro foreign exchange reference rates for 2017.
[37] State Council 2017a.
[38] State Council 2017a.
[39] State Council 2017a.

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About the 'Advanced Technologies for Industry' project

The EU's industrial policy strategy promotes the creation of a competitive European industry. In order to properly support the implementation of policies and initiatives, a systematic monitoring of technological trends and reliable, up-to-date data on advanced technologies is needed. To this end, the Advanced Technologies for Industry (ATI) project has been set up. It will provide policymakers, industry representatives and academia with:

- Statistical data on the production and use of advanced technologies including enabling conditions such as skills, investment or entrepreneurship;
- Analytical reports such as on technological trends, sectoral insights and products;
- Analyses of policy measures and policy tools related to the uptake of advanced technologies;
- Analysis of technological trends in competing economies such as in the US, China or Japan;
- Access to technology centres and innovation hubs across EU countries.

You may find more information about the 16 technologies here: https://ati.ec.europa.eu.

The project is undertaken on behalf of the European Commission, Directorate General for Internal Market, Industry, Entrepreneurship and SMEs and the Executive Agency for Small and Medium-sized Enterprises (EASME) by IDC, Technopolis Group, Capgemini, Fraunhofer, IDEA Consult and NESTA.

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