Comparison of innovation systems
China and Germany

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Studies on the German innovation system
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List of abbreviations

AHK	Chamber of Commerce Abroad
AI	Artificial intelligence
APA	Asia-Pacific Committee of German Business
APRA	Asia Pacific Research Area, Asia Pacific Research Area
ARC	Act against Restraints of Competition
ASEAN	Association of Southeast Asian Nations
BAFA	Federal Office of Economics and Export Control
BDI	Bundesverband der Deutschen Industrie e.V.
BERD	Business Expenditure on Research and Development
BfArM	Federal Institute for Drugs and Medical Devices
BFDI	Federal Commissioner for Data Protection and Freedom of Information
Bio.	Billion
GDP	Gross domestic product
BMBF	Federal Ministry of Education and Research
BME	German Association for Materials Management, Purchasing and Logistics
BMW	Bavarian Engine Works
BMWi	Federal Ministry for Economic Affairs and Energy
BRI	Belt and Road Initiative
BRP	Gross regional product
CAC	Cyberspace Administration of China
CAE	Chinese Academy of Engineering
CAS	Chinese Academy of Science
CASS	Chinese Academy of Social Science
CCPA	California Consumer Privacy Act
CEEC	Central East European Countries
CJV	Cooperative/Contractual Joint Venture
CLGCTW	Central Leading Group for Coordinating Talent Work
CNIPA	Chinese National Intellectual Property Agency
CSC	Chinese Scholarship Council
CSL	Cyber Security Law
CSTEC	Chinese Science and Technology Exchange Center
CTI	Corporate Tax Index (corporate tax)
DAAD	German Academic Exchange Service
DFG	German Research Foundation
DLR	German Aerospace Center
DLR-PT	German Aerospace Center Project Management Agency
DPMA	German Patent and Trade Mark Office
GDPR	General Data Protection Regulation
EJV	Equity joint venture
ENISA	European Union Agency for Cybersecurity (Agency of the European Union for Cybersecurity)
EPA	European Patent Office
ETDZ	Economic and Technological Development Zone
EU	European Union
EU-COM	EU Commission
EU-MS	EU member states

EV	Electric Vehicle
FDI	Foreign direct investment
FTE	Full-time equivalent
FIL	Foreign Investment Law
GBA	Greater Bay Area
GIGA	Global Institute of Global and Area Studies
GTAI	German Trade and Invest
H2020	Horizon 2020
HKSAR	Hong Kong Special Administrative Region
HNTE	High and New Technology Enterprises
HNTZ/HTZ	High and New Technology Zones
IDSK	International Data Protection Conference
ICT	Information and communication technology
IP	Intellectual Property
IPP	Innovative public procurement
IPR	International Property Rights
ISI	Institute for Systems and Innovation Research
ISO	International Organisation for Standardisation
IT	Information technology
ITU	International Telecommunications Union
JV	Joint venture
KP	Communist Party
KPC	Communist Party of China
M&A	Mergers and Acquisitions
MERICS	Mercator Institute for China Studies
MIC 2025	Made in China 2025
MIIT	Ministry of Industry and Information Technology
m.	Million
MLP	National Medium- and Long-Term Programme for Science and Technology Development
MOA	Ministry of Agriculture (China)
MOE	Ministry of Education (China)
MOF	Ministry of Finance (China)
MOFCOM	Ministry of Finance and Commerce (China)
MOHRSS	Ministry of Human Resources and Social Security (China)
MOST	Ministry of Science and Technology (China)
MPG	Max Planck Society
Billion	Billion
NBS	National Bureau of Statistics in China
NCSTE	National Center for Science and Technology Evaluation
NDRC	National Development and Reform Commission (China)
NEV	New Energy Vehicle
NFB	National Funding Body
NGO	Non-governmental organisation
NIDZ	National Innovation Demonstration Zone
NIS	National Innovation System
NMP	National S&T Major Projects
NRW	North Rhine-Westphalia

NSFC	National Natural Science Foundation of China
NSTRS	National Science and Technology Report Services
OECD	Organization for Economic Co-operation and Development
PCP	Pre-Commercial Procurement
PCT	Patent Cooperation Treaty
PIFI	CAS President's International Fellowship Initiative
PPI	Public Procurement of Innovative Solutions
PRD	Pearl River Delta
R&D	Research and Development
R&I	Research and innovation
RMB	Renminbi
S&T	Science and Technology
SAC	Standardization Administration of China
SAFEA	State Administration of Foreign Experts Affairs
SAMR	State Administration for Market Regulation (China)
SEZ	Special Economic Zones
SHIP	Shenzhen High-Tech Industrial Park
SIPO	State Intellectual Property Office of China
SME	Small and medium-sized enterprises
SOE	State-Owned-Enterprise
STEM	Science, Technology, Engineering and Mathematics
TASE	Technology Advanced Service Enterprise
Trill.	Trillion
UITP	International Association of Public Transport
UK	United Kingdom
UN	United Nations
UNCTAD	United Nations Conference Trade and Development Organisation
UNESCO	United Nations Educational, Scientific and Cultural Organisation
US	United States
USA	United States of America (United States of America)
USD	United States Dollar
VDI	Association of German Engineers
VDI-TZ	VDI Technology Centre
VgV	Public Procurement Ordinance
VPN	Virtual Private Network
WEF	World Economic Forum
WFOE	Wholly Foreign Owned Enterprise
WIPO	World Intellectual Property Organization
WTO	World Trade Organisation
ZIM	Central Innovation Programme for SMEs

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1. Introduction

1.1 Methodology and structure

In this study, China's and Germany's research and innovation (R&I) systems are compared. The aim is to identify relevant aspects for the German innovation system from China's development and to derive recommendations for action.

The study should include the following aspects:

- Control of the R&D systems Germany and China
- Access to the Chinese market
- Chinese investments abroad
- Digitalisation and Artificial Intelligence (AI)
- Chinese economic and innovation policy
- Changes in the Chinese education sector

The task was formulated in two orders:

1: Analysis of the institutional framework conditions in China and Germany, presentation of two future technology clusters as qualitative case studies.

- Analysis of the institutional framework conditions of the Chinese and German or European R&I systems with a focus on China.
- Identification of clusters in China that focus on key future technologies. The modes of operation of China's R&I policy are to be described.

2: Analysis of the Chinese and German R&I systems based on key figures.

- Comparison of the Chinese and German R&I systems based on key figures.
- Presentation of foreign direct investment in the European Union, China and Germany.

The term "national innovation system" refers to a network of institutions in the private and public sectors whose activities and interactions bring new technologies into being, import, modify and disseminate them (Welsch 2005) . In the case of Germany, the interlocking with EU structures, EU actors and EU framework conditions is added. A comprehensive comparative innovation system analysis of the two countries is not possible. The subject matter is too diverse for this and it is too difficult to distinguish it from other fields of political action such as trade and regional policy.

The study is based on three sources of information:

- Text evaluation: Approximately 300 literature sources were evaluated. Most of the text sources used on the Chinese innovation system come from Anglo-Saxon countries and Germany. Chinese sources were mainly used for data research and to understand the mode of action of innovation policy. In some of the literature used, figures are given in the Chinese currency Renminbi/Yuan (RMB). In order to make the figures assessable, they were also given in EUR for the sake of simplicity with the conversion factor 1 EUR to 8 RMB (the exchange rate in the last 2 years was between 1 EUR = 7.5 and 8.0 RMB). Values given in USD in the literature evaluated are also given in RMB. Here, the conversion factor 1 USD to 7 RMB is used.
- Of particular relevance as a source for the present study is the report and data collection on the "Monitoring of the Asia-Pacific Research Area (APRA) with a focus on China". (Frietsch et al. 2018a) . On the one hand, reference is made to this in the presentation of the Chinese R&I system, and on the other hand, the data made publicly available there is used to present the

indicators.

- Data evaluation: In addition to using the bibliometric and patentometric data from the above-mentioned monitoring study, data from the OECD was used, among others. In addition, data from the Chinese statistics authority and the Ministry of Science and Technology (MOST) were used.
- Interviews: Representatives of various groups of actors in the innovation system in Germany and China were interviewed. The interviews were based on an interview guide, which was used in an adapted way depending on the interviewee, as different focal points were discussed in each case. The interviews were summarised in short protocols. The results are included in the study in general form. In the months of May to September 2019, 25 discussions were held in Germany and 22 discussions and interviews in China. Appendix 1 contains the list of interviewees. The stakeholders contacted include German, European and Chinese students and academics in China and Germany, representatives of German higher education institutions/institutes, intermediaries from academia and industry, and representatives of the private sector.

1.2 Recommendations for action

The recommendations for action are the result of looking at China's complex and less transparent innovation system with limited access to data. The formulated suggestions are orientations. Within the framework of the study, it was not possible to compare them in detail with all the framework conditions and all the offers already available in Germany and Europe.

1. Strengthen European approaches

In China, the Communist Party (CP) has the central planning and decision-making role. The party structures encompass the country and its structures. Through these hierarchical structures of the party and the government linked to it, centralised decision-making mechanisms are given to quickly implement and further develop innovation policy instruments and regulations. The hierarchical structures have two main developmental aspects: China has a central development vision supported by all levels and central policies are acted upon at all levels of the state. It is a characteristic of Chinese innovation policy that guidelines from the central government must be taken up by provinces, cities and companies and reinforced by their own measures. Chinese actors at all levels have an incentive (e.g. career) to support these visions and measures. The size of the country and the Chinese market leads to the high and global relevance of the Communist Party's decisions.

The European Union as a whole has an economic and innovation policy strength comparable to China. However, the European association of individual democratically governed countries has fundamentally different decision-making channels and forms of implementation. Nevertheless, the EU can have a great impact through a common innovation policy vision and a Europe-wide uniform approach to the implementation of innovation-economic instruments. European long-term goals and European mission-driven innovation approaches should therefore be strengthened by Germany and supported with its own measures.

Possible examples of strengthening European action:

a. Joint strategies and implementation

Germany should advocate for the development of ambitious European goals and, in coordination with the EU Commission and the EU member states (EU-MS), set up and finance its own programmes that support and complement these common goals. In the case of such important innovation system-relevant initiatives at the EU level, platforms could also be set up in which member states, provinces, cities and also companies can discuss and coordinate their opportunities for participation so that the impact is further strengthened.

b. Innovation economy concerted actions

China's innovation mechanism is essentially based on providing major support for individual technology areas in order to develop them rapidly. In this sense, coordinated action by various actors on selected technology topics from the outset can be effective at the European level. For such coordinated "concerted actions" at the European level, there are, for example, the "Joint Programming Initiatives" in research with funding from the EU Commission and the member states. Such large-scale programmes would be similar to the Chinese mega-projects. The approaches taken so far should be evaluated and long-term mission-driven actions pursued on the basis of the results.

c. Expand existing innovation funding at European level

China creates impact through rapid action and large budgets, and has achieved technology leadership in some thematic areas in a few years in this form over the last 20 years. Chinese speed creates acceleration pressure for the innovation ecosystem in Europe.

In order to quickly strengthen innovation instruments that have an impact across Europe, we recommend expanding and further developing programmes that have already been positively evaluated. This is faster than setting up new programmes. These can be programmes of the EU Commission as well as intergovernmental programmes such as regional cross-border clusters or Europe-wide programmes such as EUROSTARS or EUREKA. Existing programmes should be looked at and, where appropriate, rapidly expanded to their best effectiveness.

2. Legal certainty for data transfer

China is an important partner and competitor for the German education, science and innovation system. It is important that the transfer of data between Germany and China is largely unrestricted, secure and legally compliant. Digitalisation is a cross-cutting and key issue here. Digitalisation of personal data is an essential sub-issue for innovative process or product development. In order to secure the competitiveness of German players through the best possible data transfer, the issue of personal data transfer between China and the EU must be resolved. In our understanding, the Chinese "Cyber Security Law" (CSL) and the European General Data Protection Regulation (GDPR) are in conflict with each other. The CSL, for example, controls and complicates the transfer of data from China to foreign countries and partly requires the disclosure of all data. Since legal certainty is directly linked to the competitiveness of German companies, it is recommended that Germany step up coordination between the EU and China on legal certainty in data transfer.

3. Innovative public procurement

Innovative public procurement (IPP) has played a role in China since 2006 at the latest. China uses IPP at different levels: at the central level, especially in "mega-projects" (e.g. building its own aircraft or producing its own computer chips) and at the local level (e.g. through the procurement of innovative e-buses). The volume of investment in public procurement has increased the uptake of new technologies on the demand side. However, no summary statistics on IPP in China could be found that would allow a statement on the efficiency and effectiveness of IPP use.

The recommendation for action for a more intensive use of PPPI in Germany is derived on the one hand from the technology-driving effects that can be observed in individual examples in China. On the other hand, IPP is also seen positively and with additional potential in Germany. It is a current topic in Europe and the OECD has advised a more aggressive approach to IPP in Germany.

4. Research funding

China carried out a reform of the research system and research funding from 2014-2017. The reform aimed at a more efficient and effective research system, especially improved project funding. To ensure coordinated implementation, a coordination mechanism known as the "inter-ministerial conference" was set up at the government level, involving not only the Ministry of Research but also the Ministry of

Finance and the Central Planning Commission.

A judgement on the success of the reform in terms of more successful research is not yet possible and data on interim evaluations are not publicly available. However, individual aspects such as greater clarity through the merging of research programmes, higher transparency through internet portals or shorter processing times can be identified, and interview partners report higher efficiency of project funding after the reform.

The proposal to look at the German system of project funding is derived on the one hand from the optimisation process in China. On the other hand, an analysis of German project funding would currently be appropriate as a complement to the discussion on fiscal research and development (R&D) funding and the establishment of the Agency for Leap Innovation. An analysis of German research funding could pursue similar goals as the reform in China, e.g. acceleration of procedures and administrative simplification. Innovative aspects should also be considered, such as digital transformation in funding processes.

5. Expansion of China competence

Chinese partners are highly important for the German innovation system today and this relevance will continue to increase in the coming years. A lack of language skills and knowledge about modern China are still obstacles to cooperation with China in research and among companies. Especially when innovative processes are to be developed or implemented, direct and trusting communication is an essential factor for success. Mutual understanding, the success of establishing German companies in China and the integration of Chinese companies in Germany depend on communication and mutual knowledge.

a. Language and Modern Chinese Competence

It is in Germany's interest that learning Chinese becomes widely popular among Germans and that this is also supported in the best possible way. Current figures show a decline in language learners in Germany, in contrast to rising numbers in the USA and France. The learning of the Chinese language should be promoted in Germany in a special way. In addition, the expansion and networking of institutions for the study of China and the teaching of modern Chinese language skills should be supported.

b. Bridging function of Chinese graduates in Germany

China has an active policy of sending students and academics abroad and bringing them back with degrees and skills. China benefits from education in Germany, which is not financed by tuition fees as it is in the USA, for example. Whereas in the past, Chinese educated abroad were often active in foreign companies later on, today they are increasingly going to Chinese companies in their home country. The reasons are manifold. One reason is that modern Chinese companies are now perceived as attractive employers and offer good working and promotion conditions.

Since the Chinese educated in Germany are a valuable resource for Germany as a location for innovation, programmes should be developed to make Germany attractive as a place to work and German companies or research institutions (in Germany and in China) attractive for Chinese talent (possibly through visa facilitation, more alumni programmes, support of universities for social integration already as students, special job fairs for Chinese interns or graduates, etc.). Job and career opportunities in German companies and public institutions should be presented. Successful Chinese in the German system (such as the former Chinese minister Wan Gang) should be made visible as "testimonial donors". Chinese graduates in Germany can take on an important bridging function, for example, in the establishment of Chinese companies in Germany, in the creation of technology profiles of Chinese partners or in the establishment of German companies in China. Chinese graduates from other EU countries should also be considered.

The current discussion on the outflow of knowledge and technologies via individual Chinese students or researchers to China (also linked to the dual-use issue) must be taken into account and critical areas defined and protected. Universities and employers must be informed as best as possible about relevant framework conditions and individual cases. However, this should not overshadow the predominantly uncritical and positive work of Chinese in Germany at universities and companies.

6. Chinese investments in Germany

Chinese investments in Germany have a predominantly positive effect on the German economy and are desirable. Nevertheless, it is important to discuss whether the Chinese state is behind some Chinese investors and financing is covertly subsidised in an unfair competition. Related to this is the question of whether the German state should step in as a buyer if a company cannot be bought by German or European investors but is relevant to the industrial sector or basic services in Germany. The current broader understanding is that the mechanism of EU investment screening is appropriate so that such cases become known and then a decision has to be made on how to proceed in each individual case. However, this should not obscure or slow down the fundamentally positive effect of Chinese investments.

In order to strengthen the intended positive effect of Chinese investments on German innovation, the investments should be guided by German economic needs as far as possible or be in the interests of both partners from the outset. This includes, for example, the creation of technology profiles of Chinese companies, regions or clusters. Targeted "technology scouting" in China and the targeted search for and recruitment of Chinese investors are also part of this. The goals and strategies of German and Chinese investors are often different and must be as well-known as possible on the German side, which also leads to different recommendations and approaches depending on the sector.

There are examples of German innovation agencies or cities that have been successful in actively approaching Chinese institutions and companies. Since China is very large, changes rapidly and new actors are always emerging or evolving, these approaches should be expanded. Germany should know the economic landscape in China as well as China knows Germany or Germany knows the USA. An active German approach will in turn make it easier for the Chinese partner to obtain approval for its foreign investment. This approach is also viewed positively on the Chinese side.

7. Seize opportunities in China

Foreign investors, start-up actors or even scientists and students who invest in technology development or are involved in technology development are desirable partners in China. There are various incentives to locate, e.g. in technology zones, science parks or incubators. However, China's innovation system is complex. The framework conditions, structures, financing options, actors, etc. are diverse. In some cases, settlement is linked to attractive financing or tax breaks, but these framework conditions are little documented and also rarely available in English. In China, personal contact, direct and repeated enquiries and the building of trust are still essential factors for success. German companies, especially larger ones that have been active in China for a longer period of time, often have corresponding departments that deal with China's structures and maintain contacts. Smaller companies or German research institutions do not have such facilities and there is a risk that they are not sufficiently informed about the opportunities and risks of an operation in China. There are German and European information and support services for German innovation actors who want to get involved in China. The AHKs and consultancies in China, for example, offer support. With European projects such as "Chinainnovationfunding.eu" or the "International IPR SME Helpdesk", the EU Commission also offers assistance. However, so far these are partly measures that act locally, are limited in time or have a thematically narrow mandate. The current formats do not cover China's diversity. In particular, too little information is prepared and published on the many support options at the provincial and city level. After taking stock of the current formats, the expansion of existing or the establishment of additional advisory and support measures could therefore help to fill knowledge gaps and offer better opportunities for

German actors.

2. Innovation systems: The role of state guidance

National innovation systems are understood as a summary of the institutions, actors, their steering instruments and influencing factors that conduct scientific research, collect and communicate knowledge, develop technologies and produce and disseminate innovative products and processes. These actors are linked to each other by an extensive system of rules and relationships. (Belitz and Schrooten 2008) .

Germany and China each have differentiated actor networks and employ a variety of intervention and steering instruments using a professional administration (Gerybadze 2015) . There are significant differences in the two systems, which can be seen in the form of differing priorities for the respective goals, the roles and opportunities for influence of the individual actors, and the use of steering instruments. (Fraunhofer Institute for Systems and Innovation Research ISI; Science Information Service (idw) 08.04.2019) . Basically, there are two different forms of society, law and government. The different political, historical and social environments in which both systems are embedded and the resulting framework conditions for the respective innovation system also have a decisive influence on the increasingly competitive situation. (Frietsch et al. 2018b) .

The aim of the study is to compare aspects of both systems. This should make it possible to identify the particularly successful aspects of the Chinese system and, above all, those that particularly influence Germany.

The central goals of the Communist Party and the Chinese government, which also form the basis for innovation policy, are, according to the assessment of the former US administration (Harvard Fairbank Center for Chinese Studies 2019) the following (examples of innovation-relevant aspects according to their own classification):

1. Domestic and regional stability (e.g. Great (Internet) Fire Wall, NGO Laws, Cyber-Security Law, Social Scoring)
2. Continued growth of national economic power (e.g. Belt and Road Initiative, industrial policy, artificial intelligence strategy, Made in China 2025)
3. International respect and recognition of the legitimacy of the governance model (involvement in multilateral institutions, e.g. in standardisation).
4. Sufficient strength against external pressure (building up own financial instruments (e.g. Asian Investment Bank), investing in own technologies to become more independent (e.g. mega projects like Chinese aeroplane, etc.)
5. Consolidation of the national borders

Forty years after the start of China's reform and opening-up, the country can boast impressive progress in terms of its scientific and technological development. The Chinese government has responded to many of the challenges that China has faced and continues to face as a nation. For many years, the country has focused on education, research and innovation as the key factors for its further development. President Xi regularly refers to the country's innovation-driven development strategy and emphasises China's goal of becoming a global innovation leader by 2049:

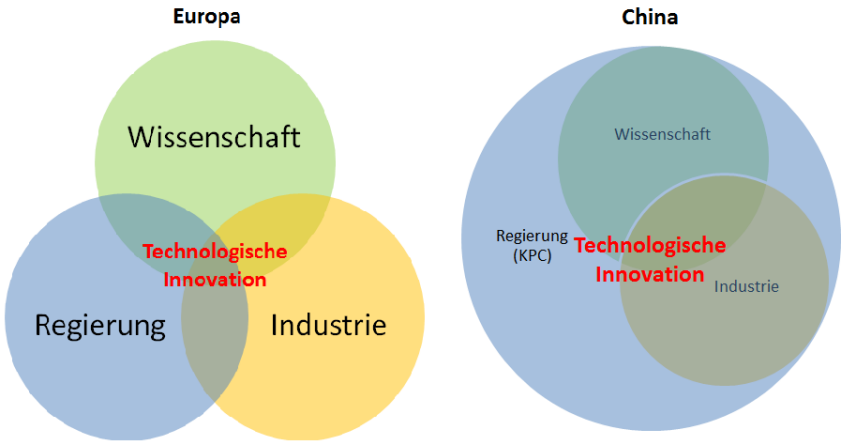
"China has put its mind and heart and soul to not just being an innovator, but to being, in the words of Chinese president Xi Jinping, 'master of its own technologies. '" (Atkinson and Foote 2019, p. 2)

China's original economic model was largely dependent on foreign technologies and high resource consumption. China was considered the workbench of the world (Wübbeke et al. 2016) . "*Against this*

background, a shift towards innovation-driven and sustainable growth and [...] upgrading of industries through new technologies and digitalisation began. Long-term industrial policy programmes such as the 'Made in China 2025' as well as industry- and sector-specific programmes (e.g. on artificial intelligence) support the industrial policy shift. At the same time, the development of the science and technology system is being driven forward in order to become more technologically independent" (Frietsch et al. 2018a, p. 52) .

On China's path so far and also currently, state control plays a prominent role. Since the 1980s, the Chinese government has been trying to expand the innovation system through industrial policy measures and incentive mechanisms (see Chapter 5.1). More recently, experts have emphasised the growing role of "private" companies in the innovation process, for example in the area of mobile payment. However, the success of these "private" innovators was also possible because of the corresponding state-created freedom and incentive system. (Soo and Deng 2019) . What is undisputed is that in China, compared to Europe, there is a much closer interlocking of party, government, science and industry, which shapes the entire innovation system.

Figure 1: Degree of interconnectedness of the different sectors in the innovation system



Wissenschaft = Science, Industrie = Industry, Regierung = Government, Technologische Innovation = Technological Innovation

Source: own presentation, based on a presentation by the IISS (The International Institute for Strategic Studies) 2018: Emerging technology dominance: what China's pursuit of advanced dual-use technologies means for the future of Europe's economy and defence innovation. [no longer available online, was changed after a suggestion from a lecture by N. Pieke].

The state's course in recent years is a vertical industrial policy based on individual technologies or sectors. This contrasts with the more horizontal innovation support policy in Germany, where the state predominantly leaves the setting of topics to the free market. There are numerous examples of the consequences of state control in China, for example in the development of electromobility or in the wind energy sector. (Soo and Deng 2019) .

Textbox 1: State innovation funding for electric vehicles

Since 2001, China has seen and promoted electric vehicles (EVs) as an important technology. Since 2017, Shenzhen-based BYD has become the world's largest EV vehicle supplier and several other companies have established themselves (e.g. WM Motor, Xpeng Motors, NIO). In 2017, this development was subsidised centrally and locally by the Chinese government to the tune of USD 7.7 billion (equivalent to about RMB 53.0 billion) for both manufacturers and buyers. In the same year, 770,000 EVs were manufactured in China and sold domestically (199,000 in the US) (Soo and Deng 2019).

Textbox 2: Technology and market leadership in wind energy

In 2006, the Chinese government launched a policy initiative to build a strong national wind energy industry while developing it as an important energy resource. This initiative was accompanied by scientific research, regulatory measures and specialised administrative measures such as the designation of appropriate areas for wind farms (National Development and Reform Commission 2006). This initiative was accompanied by the granting of lucrative concessions for wind energy production and own feed-in regulations. This coordinated mix of instruments led to a rapid increase in wind energy use in China (Lewis 2011). Before 2000, there was no national wind turbine market; installed wind turbines played only a small role until 2005. From 2006 onwards, the number of installed wind turbines doubled and from 2010 onwards, about 30 % of the world's turbines were installed in China. Already in 2013, China had the highest wind energy production in the world with 91.4 gigawatts and at that time the Chinese industry (Goldwind, Guodian United Power, Mingyang Wind Power as well as Sinovel) was one of the major players worldwide (Chinese Wind Energy Association 2014). (Huang and Sharif 2016, p. 67).

In recent years, companies (Huawei, Tencent, Baidu, etc.) have developed into innovation drivers of the Chinese economy, partly with state assistance, but also often taking advantage of the greater freedoms during the reform period through their own initiatives. This impressive development is also leading to increasing involvement in world markets for these companies. Nevertheless, it is clear that the state also has a say in these companies when it deems it necessary. (Bartsch 2016) .

2.1 Government structure in China with innovation relevance

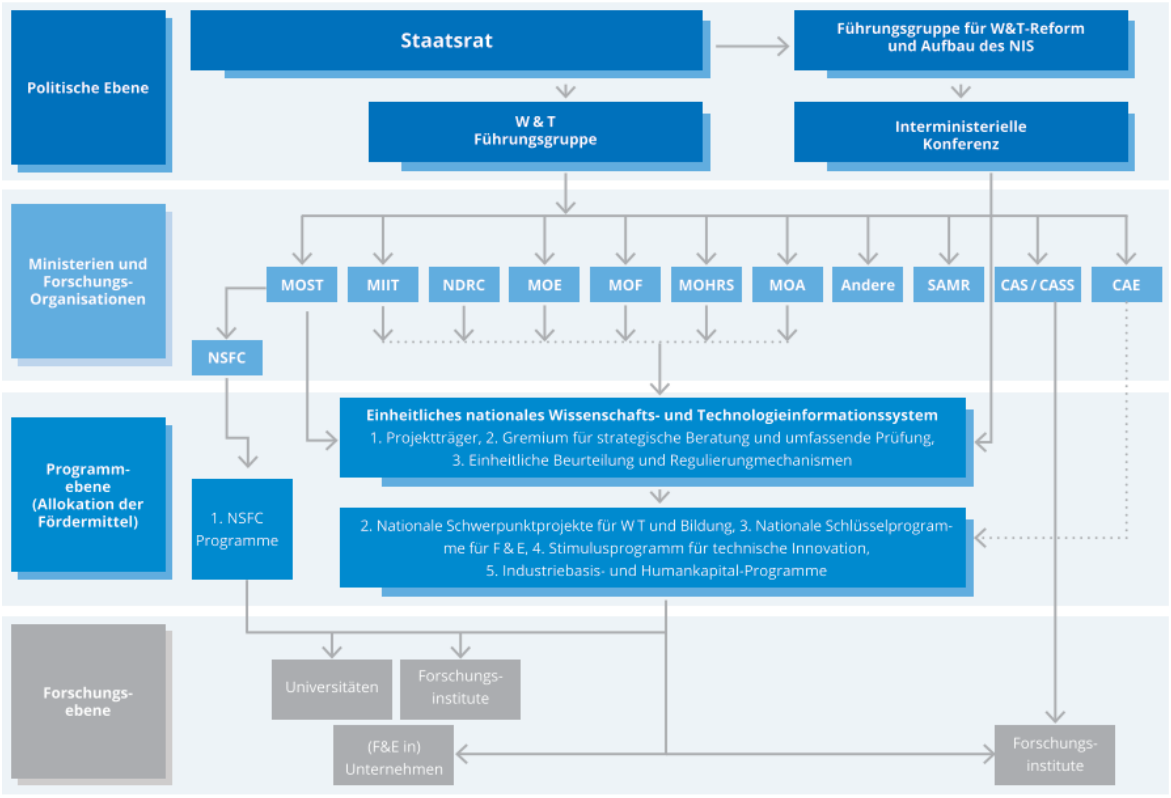
The pronounced role of state control for the Chinese innovation system is rooted in the institutional structure of the Chinese state and the interwoven role of the communist party. At the same time, there is a contradiction in the strictly hierarchical top-down direction of content and the size, disparity and high complexity of the system, which does not actually allow for any uniform guidelines. Chinese government policy must therefore elaborate and formulate all guidelines in such a way that, although centrally prescribed, they can be adapted to regional and local conditions. Therefore, regulations often appear rather general and unclear. Often, regulations are published as "regulations on trial" or "provisional regulations" and are, as it were, first tested. German actors in Beijing say in interviews that they do not expect clear guidelines from the Chinese side, but are in a mode of "constant adaptation" (Interview 2019).

It is only through the feedback from the regions on central guidelines and the then incipient convergence of positions by the central and local actors that a system suitable for the various participants develops. In this process, the authority of the Communist Party is an essential partly invisible factor. The expectation of the party to participate in the central initiatives leads to all local and sometimes private actors engaging positively with these initiatives and submitting their own input or initiatives. There will

also be negative feedback, but this will not be dealt with publicly.

The institutional reforms in various areas of the central science and innovation system that have been implemented and started since the change of China's political leadership in 2012/2013 have currently been summarised by GIGA in Figure 2 (Frietsch et al. 2018a) . The authors mainly address questions about the new governance structure of the science and innovation system as well as questions about new instruments and goals. The reform primarily affects the centrally supervised and financed structures and budgets. At the same time, of course, the reform is also reflected at the local level, as the respective central ministries and structures are mirrored in the provinces. The research ministry in a province is subordinate to the central research ministry (unlike in Germany).

Figure 2: "Governance" structure of the Chinese state science and technology system, end 2018[1)]



1) Abbreviations:

NSFC	National Natural Science Foundation of China	MOHRSS	Ministry of Human Resources and Social Security
MOST	Ministry of Science and Technology	MOA	Ministry of Agriculture (Ministry of Landscape)
MIIT	Ministry of Industry and Information Technology	SAMR	State Administration for Market Regulation
NDRC	National Development and Reform Commission	CAS	Chinese Adacemy of Science
NIS	National Innovation System	CASS	Chinese Adademy of Social Sciences
MOE	Ministry of Education	CAE	Chinese Adademy of Engineering
MOF	Ministry of Finance		

Source: Frietsch et al. 2018a, p. 53

Figure 2 shows the structure of the steering organisations of the Chinese research system at the central level in 2018. At the political level, the State Council as well as the leadership groups and the Interministerial Conference play crucial roles. According to Schüller, the conference, which was founded in 2015, is (Frietsch et al. 2018a) the "*most important coordination and decision-making body for public research funding*" as an "*example of top-level design, through which structural and institutional barriers within the governmental and administrative apparatus are to be overcome and*

efficient implementation of policy goals is to be achieved." (Frietsch et al. 2018a, p. 54) . At the level of ministries and research organisations, particular mention should be made of the Chinese Ministry of Science (MOST): "*In the field of research planning and funding as well as in evaluation, the ministry now plays a key role .“* (Frietsch et al. 2018a, p. 55)

Further essential aspects of the reform were the reorganisation and integration of the previous multi-layered system of support into five pillars (DLR Project Management Agency and VDI-TZ 2015) :

1. "National Natural Science Foundation China" to improve sources of innovation (basic research, exploratory cutting-edge research, human resource development).
2. "Major National S&T Projects" to solve important problems within a set timeframe by focusing on strategic products and the most important industrialisation goals and using national synergies
3. "Key National R&D Programme" for continuous support of application-oriented research with a focus on research cooperation between authorities, industry, regions or with other countries.
4. "Incentive Program for Tech Innovations (Fund)" for the provision of venture capital to industrialise scientific and technological achievements
5. "Industrial Base and Human Capital Programme" to improve research infrastructure

According to statements by Chinese interviewees, there is currently no evaluation of the effectiveness and impact of the reform, as the entire new system was only introduced "a short" time ago (interviews 2019). The aim of the reform was to make administration more efficient while at the same time clearly emphasising the top-down approach, as well as to improve research results.

"China is currently undergoing an ambitious reform of its national funding system for science, technology and innovation (STI) as well as its institutional setup. The reform, combined with an increasing national budget allocated for research and innovation (an average annual increase of 10 % in the last three years), aims to fully unleash China's innovation-driven development strategy.“ (DEVELOPMENT Solutions Europe Ltd. 2018, p. 6)

2.2 Innovation-relevant strategies in China

China avoids the word strategy in political contexts because it is linked militarily in Chinese (the word "strategy" in Chinese consists of 2 characters 战略 (*Zhan Lüe*) and 战 (*Zhan*) meaning war or battle). Instead, strategic documents are referred to by terms such as approaches, initiatives, plans or the like. The documents often differ from Western strategy papers in terms of content, style or target concreteness. The Chinese documents are to be understood as guidelines, they serve as a framework for science, industry and society and are primarily directed inwards. They are less concrete action-guiding process documents with clear specifications, concrete implementation tools and measurable goals (interviews 2019). Documents overlap in terms of time and content. Plans and programmes are often published with ambitious target figures and thus convey relative concreteness. However, even these figures are not quantifiable metrics to verify programme success, but rather serve as benchmarks. Some key figures on planning and target setting for individual provinces can be found in official documents. However, robust figures on the implementation and progress of individual initiatives and plans are hard to find. Detailed monitoring and progress reports are not publicly available. The achievement of objectives of plans is hardly measurable for outsiders.

The framework for Chinese research and innovation policy is set by national plans. To achieve the goals stated in the plans, the government uses its own instruments at the central level, such as increased research funding for individual areas. At the same time, however, it expects local actors to participate, from provincial and municipal governments to universities and business enterprises. Above all, state-

owned enterprises (SOEs) and state-affiliated companies are expected to implement central requirements constructively. However, the private sector, which is more distant from the state, also always pays attention to state requirements. The social credit system, which is currently being introduced, is also intended to systematically record the state-appropriate behaviour of enterprises. (Dorloff 2019; Cheng 2019) .

An overarching motive of the various current plans is the desire to make Chinese companies independent innovators, following the example of companies from Japan, Korea or Taiwan, and thus to make the Chinese economy as a whole more independent from foreign countries. This motive can be found, for example, in the following plans: "13th Five-Year Plan for Science and Technology", "13th Five-Year Plan for National Informatization", "The National Cybersecurity Strategy" and "Made in China 2025 Strategy". (Atkinson and Foote 2019, p. 3).

For the national orientation, the "Five-Year Plans" and the "Medium- to Long-Term Development Plan for Science and Technology (2006-2020)" are the main overarching documents. For sub-sectors of the economy, additional plans are drawn up for concretisation, such as the Made in China 2025 document on innovation and technological performance. In recent years, Chinese planning documents have also increasingly aimed at international cooperation and direct Chinese influence abroad. The Belt and Road Initiative (BRI) is a visible initiative here.

2.2.1 Medium- to long-term development plan for science and technology

The "Medium to Long Term Development Plan for Science and Technology (2006-2020)" (MLP), published in 2006, is considered a decisive turning point for the further development of the Chinese innovation system (Atkinson and Foote 2019) . The overarching goal is to promote independent innovation capacities. In 2006, China set the goal of increasing the share of national research and development (R&D) in GDP to 2.5 % by 2020. (Soo and Deng 2019) . In addition, the MLP identifies industries, technologies and research areas that are considered central to the further development of the Chinese innovation system and to which particular importance is attached from this point onwards at the latest, which is also reflected in corresponding funding programmes, for example. According to Frietsch et. al., *"the increase in economic performance and the expansion of the national innovation system in China [...] in the years since WTO accession in 2001 and especially after the publication of the medium- to long-term plan on science and technology in 2006 was also significantly supported by the development of the science system. In addition to massive investments in science - especially through an expansion of institutional funding at universities and the Chinese Academy of Sciences, but also through numerous programme and project funding - this can be evidenced by various output indicators of the science system."* (Frietsch et al. 2018a, p. 85) .

The guidelines for the further development of China's innovation system laid down in the MLP were then taken up in the subsequent five-year plans, further specified and thus translated into the development of structures and framework conditions in order to come closer to the goals set. Measured by the example of R&D expenditure as a percentage of GDP, China is following its plan targets and, according to OECD data from 2017, achieved a value of 2.13 % (see Figure 5).

2.2.2 Current 13th Five-Year Plan 2016-2020

In the 13th Five-Year Plan (2016-2020), the Chinese government published its long-term plan targets, which also includes the period 2030 to 2050:

- *"In 2020, China wants to be among the 15 most innovative countries in the world. By that time, advances in science and technology should contribute more than 60 per cent to overall economic growth and knowledge-based services should account for 20 per cent of GDP. R&D intensity is expected to increase to 2.5 per cent in 2020. [...] The National Innovation System should provide stronger support for innovative forces, create more synergies between science and business, provide stronger protection for intellectual property rights and promote*

entrepreneurship.

- *In 2030, China wants to be one of the leading innovation countries. This is expected to be accompanied by significant increases in international competitiveness and the general level of development. The increase in R&D intensity to 2.8 percent by 2030 should enable China to play a leading role in many strategic areas. [...] To achieve this, the NIS [National Innovation System] is to provide stronger support for synergies between science and business and promote a culture of innovation based on high legal and moral standards.*
- *By 2050, China aims to achieve a strong global leadership position and be a hub for science and innovation. [...]As an international hub for science and innovation, China aims to be attractive to the best talents and international leading scientists, as well as to have a group of world-class research institutes, universities and innovative enterprises . "* (Frietsch et al. 2018a, pp. 56-57)

China is ranked 14th (Germany 9th) in the World Economic Forum's 2019 Global Innovation Index (2018: China 17, Germany 9). (World Economic Forum (WEF) 2019) . With the current Five-Year Plan, there also seems to be a visible shift towards civil-military research and development cooperation. Thus, various aspects in the field of R&D in the current Five-Year Plan also have military relevance: Aircraft engines, gas turbines, quantum communications and others. This also includes China's ambitions in the field of nuclear fusion or the development of multifunctional satellites. The USA therefore sees a clear deepening of China's military research ambitions in the current five-year plan. (Defense Intelligence Agency USA 2019, p. 105) . This stronger interlinking of military and civilian research is also quite openly the goal of current R&D policy:

"We will improve systems and mechanisms for integrating military and civilian development as well as the systems concerning organisational management, work, and policy." (National Development and Reform Commission (NDRC) 2016, p. 214)

2.2.3 Made in China 2025

The Made in China 2025 Initiative (MIC 2025) is a 10-year plan published in 2015 that aims to develop China as a technology nation. The country is to become the global technological leader in various fields. Ten key industries are defined in which technology leadership is to be achieved by 2049. These industries are in detail (State Council of the People's Republic of China 2015c) :

- High-tech shipbuilding and maritime industry
- Advanced rail transport
- Agricultural machinery
- Aerospace
- Biopharmacy and medical technology
- Next generation information technologies
- Energy and power generation
- Computer-controlled machines and robots
- Vehicles with alternative drives
- New materials

It is the transfer of the hitherto national strategy of vertical technology support to the world scale. China is to emancipate itself further from the model as the "workbench of the world", which can no longer be sustained in the long term due to rising production costs at home and competition from other, cheaper-producing countries. In order to avoid falling into the "middle income trap", the economy is to generate

urgently needed economic growth with the help of the Made in China 2025 strategy, especially in the high-tech sectors. (McBridge and Chatzky 2019) .

Made in China 2025 was inspired by the German Industrie 4.0 concept, among others, but goes much further, as it involves much stronger and more concrete state involvement and is a form of industrial policy (Zenglein and Holzmann 2018) . In contrast to Industry 4.0, it is also about replacing imports with domestic production and thus about concrete effects on foreign trade. (McBridge and Chatzky 2019) . Overall, the strategy is so broad that one can speak of a general modernisation of production. Many companies are also trying to secure subsidies beyond the specifically mentioned high-tech sectors. (Coym and Kedl 2019) .

One reason for the development of MIC 2025 was the desire to be less dependent on foreign partners. China could boast a large industrial landscape, but it was weak in terms of quality, brand visibility, its high dependency and low productivity (Publications Office of the European Union 2019, p. 14) .

Concrete goals of MIC 2015

MIC 2025 has mainly concrete national targets: for example, by 2025, 80% of national demand for control IT tools should be provided by Chinese companies; 70% of robotics products and 60% of "big data" applications; 60% of IT applications in smart manufacturing; and 50% in industrial software (Atkinson and Foote 2019, p. 3) . These goals are to build a competitive industry in China that creates jobs, reduces dependencies and creates value in the country. (Publications Office of the European Union 2019; Institute for Security & Development Policy (ISDP) 2019). .

The initiative was published in May 2015 together with various information on measures and instruments. (State Council of the People's Republic of China 2015b) including that "National Innovation Demonstration Zones" (NIDZs) will be a key new element of the initiative (see also Chapter 5.3, p. 110, on innovation support instruments) (Publications Office of the European Union 2019, p. 13).

The following steps after 2025

The target year of the initiative 2025 refers to the end of the first phase, in which the foundations are laid. By then, a relevant number of companies should have reached a global scale or be able to keep up with Western countries. The following phase up to 2035 should bring the Chinese economy to the same level as that of industrially competitive countries. By 2049, the date of the 100th anniversary of the People's Republic of China, the country should be a global leader. (Publications Office of the European Union 2019, p. 13) .

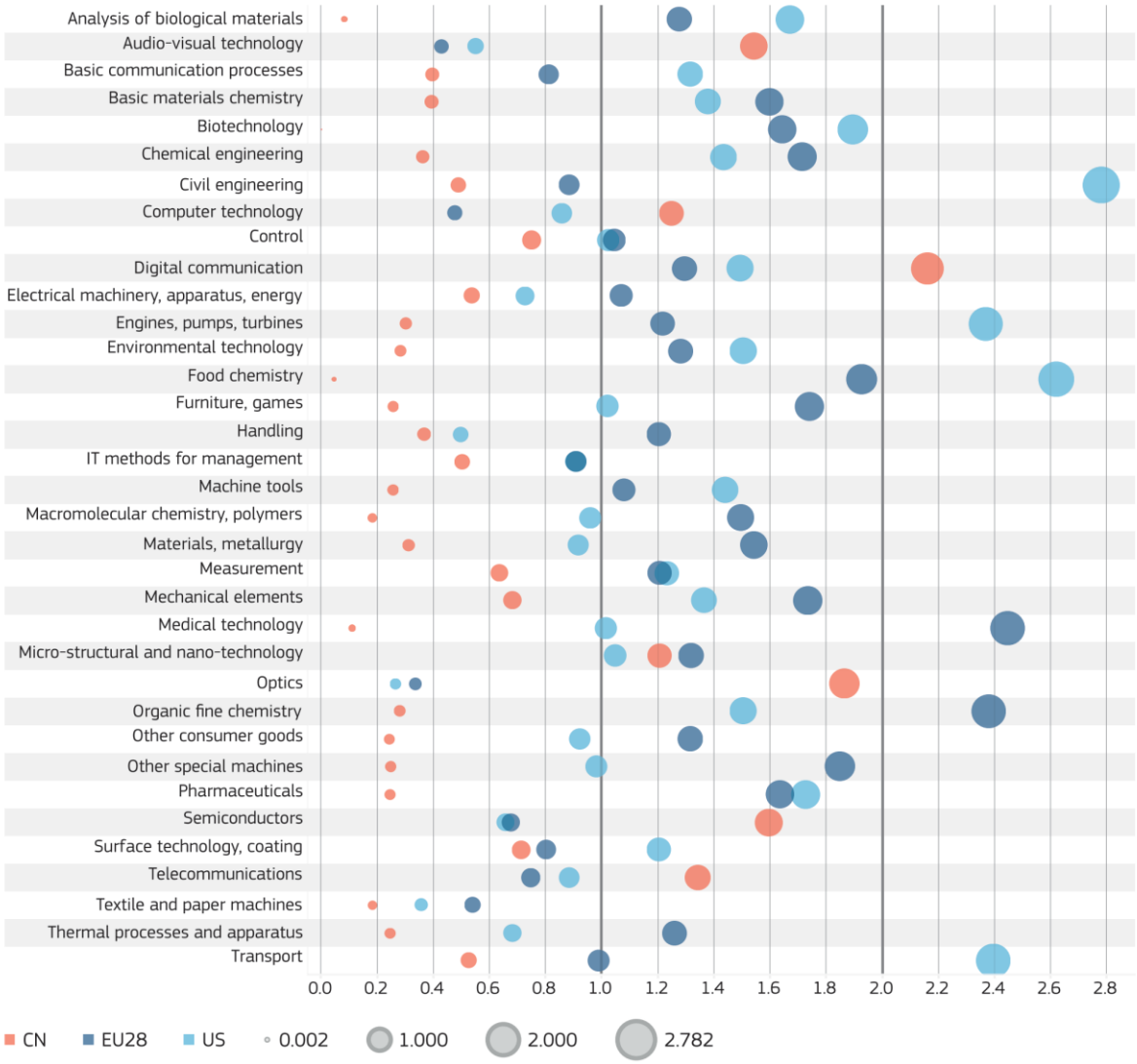
Implementation of MIC 2025

The implementation of MIC 2025 has been centrally decreed as explained above; the project is coordinated by the State Council and managed by the Ministry of Industry and Information Technology (MIIT). For example, the Chinese Academy of Engineering (CAE) plays a role as a promoter for the National Demonstration Zones and Pilot Programmes. (Publications Office of the European Union 2019, p. 15) . As with other programmes in China, a variety of other initiatives at provincial, district and city levels play an important role.

A key intention of MIC 2025 (as with other plans and initiatives) is to increase the efficiency of the innovation system. This is visible in the reform of the funding system, the restructuring of research funding agencies and also the increasingly important evaluation of programme/project results. Within this framework, the newly launched "Mega-Project" programmes in particular aim in the direction of strong vertical technological development. At the same time, legislation and regulation will be reviewed and, if necessary, adjusted if they hinder the achievement of the MIC 2025 goals. (Publications Office of the European Union 2019, pp. 14-15) .

From the perspective of the European Union 2019 analysis (Publications Office of the European Union 2019, p. 64) China has the capabilities to achieve the MIC 2025 goals. Currently, however, the Chinese companies that are successfully active worldwide still have a rather narrow specialisation in the IT applications sub-sector, especially in the areas of audiovisual applications, optical applications, telecommunications, semiconductors, etc. The EU or the USA have a broader and more balanced product portfolio. The EU or the USA have a broader and more balanced product portfolio in industry and also in research (see Figure 3).

Figure 3: Depiction of sector-related company strength based on patent applications1)



1) The Industrial R&D Investment Scoreboard, published annually by the EU, takes into account the 2500 companies worldwide with the largest R&D expenditures. Based on this, the scoreboard shows the strengths of companies in China, the USA and the EU in individual subject areas. This shows that companies from the USA and the EU can claim technological leadership in significantly more areas. China is only superior in a few areas, especially in digitalisation and information technologies.
Source: Publications Office of the European Union 2019, p. 62

China's vertical industrial policy

China has been successful in the past with its consistent vertical industrial and innovation policy, see e.g. the successful examples of digital communication and optical technologies (see Figure 3). Rapid technology development is possible mainly through the focus on single themes/technologies, the combination of incentives and subsidies, the use of innovative public procurement, appropriately theme-focused research funding, and the implementation of initiatives at many levels by a number of actors

and instruments owing to the authority of the Party.

These technologies are rapidly improved in the large national market through multiple applications from one technology stage to the next. The accompanying market dominance of domestic suppliers - also due to market foreclosure - does entail the risk of diminishing pressure to innovate, but this pressure will increase again when the technology enters the global market. The already existing strengths in IT and telecommunications will accelerate and improve these processes in other technologies, especially since the further development of other products is often essentially also about digitalisation (Shi-Kupfer and Ohlberg 2019, p. 11).

The approach is complemented by (forced) technology transfer, joint ventures, foreign acquisition of technologies/firms/patents, training of experts abroad and other measures to exploit international know-how. This systematic state support of the Chinese economy is criticised by the current US administration, among others (Rubio 2019) .

However, the question arises whether this vertical industrial policy, which has been successful for individual technology developments, can also work for the technology breadth formulated by MIC 2025. The broader China spreads its support measures, the lower the impact for individual technology approaches. At the same time, China will increasingly experience the "innovation paradox" as a challenge for all innovation-driven economies: The higher the level of technological development, the more effort must be expended to reach the next higher level. (Xavier Cirera, William F. Maloney 2017). This effect will occur all the faster and more strongly the further China's industry moves out of the protected national space into international technology competition.

International reactions to MIC 2015

The perception in the West of MIC 2025 is dominated by the concern that market access in China for foreign products is being reduced because they are being systematically replaced by domestic products. This may be through direct preference for Chinese firms or through direct and indirect regulations that disadvantage foreign firms. (Publications Office of the European Union 2019, p. 16) . A technology leap in China, supported by substantial state funds, will primarily benefit Chinese firms and consumers. However, an overall broader technology and industrial market in China also offers more opportunities for foreign suppliers. The developing higher costs for Chinese firms lead to improved competitiveness of foreign firms, in China and also internationally.

In addition to limited market access, Made in China 2025 criticises China's handling of intellectual property and targeted Chinese investments abroad. MIC 2025 is interpreted by the USA as an attack on Western market economies and their innovation potential. (Zenglein and Holzmann 2018) . The current US administration sees Chinese trade practices, such as subsidies for national companies, on the one hand as one of the causes of the US's persistent trade deficit, and on the other hand as direct competition between two economic and political systems. In the eyes of the US, a struggle for economic dominance and political strength is being fought in which China represents the most significant economic opponent. The main concern is China's industrial policy, which is a mix of state planning, interventionism and market reforms. (Mildner and Schmucker 2019) . One consequence of this state-led model, they fear, could be the control by a geopolitical rival of entire supply chains and thus entire industries. From the US perspective, China's growing influence in global industry also poses a national security problem. (McBridge and Chatzky 2019) . Such reactions came as a surprise to the Chinese leadership: for a long time, the Made in China 2025 strategy was seen primarily as an opportunity to strengthen economic cooperation abroad. Since this view was not shared at the international level, Chinese media have recently refrained from reporting on the strategy. (Zenglein and Holzmann 2018) . The Western interpretation of open competition and confrontation remains: in a report by the US Senate Committee on Small Business and Entrepreneurship, Made in China 2025 was summarised as the Chinese leadership's way of setting new conditions for international competition. (Rubio 2019) . Former

Republican leader Marco Rubio stated in a foreword:

"The 'Made in China 2025' industrial plan announced in 2015 by the Chinese government makes their goal clear. China aims to become the global leader in innovation and manufacturing. This would be an unacceptable outcome for American workers." (Mildner and Schmucker 2019, p. 11)

However, there are also Western assessments that see the positive sides of the planned next technological step in the Chinese economy. For example, the UK Trade and Invest /China-Britain Business Council concludes that MIC 2025 will create opportunities for the UK:

"Despite its overt theme of Chinese technological independence, MIC 2025 is in reality a source of great opportunity for UK companies that can help China to implement the changes required." (UK Trade & Investment and China-Britain Business Council, p. 6)

This position is complemented by the demand for ambitious and common goals, as also formulated by the BDI and Cameron. (Mair et al. 2019) and Cameron have also formulated:

"The EU has to invest more in understanding China, which is a growing and formidable rival. EU leaders need to spend more time discussing China and agreeing a comprehensive approach covering all sectors. It should work with likeminded partners where there are shared interests concerning China." (Cameron 2019, p. 1)

Balance sheet of MIC 2025

As part of MERICS studies, Zenglein and Holzmann (2018 and 2019) conducted evaluations of MIC 2025. They partly relied on figures from the Chinese MIIT (Ministry of Industry and Information Technology). The following observations can be made for individual aspects.

Three areas in which China sees itself far ahead, for example, are telecommunications, the rail sector with its high-speed technology, and the energy sector in the ultra-high-voltage segment. However, there are also deficits here, for example in sensors and semiconductor chips. (Zenglein and Holzmann 2018).

According to a recent report by MERICS, MIC 2025 can point to successes in the areas of smart manufacturing, digitalisation and future technologies, where Chinese companies are playing an increasingly important role. For example, seven of the top ten battery manufacturers for e-vehicles come from China, and Chinese telecoms companies ZTE and Huawei are leading the roll-out of 5G networks. But here, too, China remains dependent on foreign core technologies. (Zenglein and Holzmann 2019) . In a report by the Leibniz Information Centre for Economics, Kunze concludes that a large part of the ten MIC 2025 core industries are undergoing a transformation process. Currently, the industries are *"still in the lower to middle range of the global value chain".* (Kunze 2018, p. 7) .

Some experts suggest that China will not be able to achieve all targets across the board by 2025 (Kunze 2018) . At the beginning of 2018, the government provided information on the areas to be targeted by China's industrial policy efforts. On the one hand, there is a clear focus on artificial intelligence. On the other hand, the government has identified regionally different industrial focal points to enable a focus on local strengths. This is to prevent provinces from aiming at all targets at the same time and then not being able to fulfil any of the targets well. (Zenglein and Holzmann 2018) . However, since it is still not possible to quantify how much money has gone into MIC 2025 in the meantime, it is hardly possible to evaluate it. (Zenglein and Holzmann 2019).

2.2.4 Belt and Road Initiative

China's Belt and Road Initiative (BRI) is a geopolitical strategy that aims to open up new trade routes, build infrastructure, and promote cultural and scientific exchanges with numerous countries around the world through international cooperation. China's President Xi first unveiled the project in 2013 and it is seen as his "signature-project" by whose success he is measured (European Union 2018; Belt and Road Portal (中国 "一带一路 "网) 2019).

Despite the high level of international attention the initiative has received since then, there is no official document documenting the number of countries involved. As a result, the numbers of countries participating in BRI vary from 80 to over 130. Furthermore, it is hardly possible to distinguish BRI projects from conventional collaborations. An overview of the overall financial framework is also very difficult, as the information varies greatly depending on the source. According to the Chinese Ministry of Commerce, investments by Chinese companies in the period from 2013 to 2018 amounted to 90 billion USD (approx. 630 billion RMB). (Duchâtel 2019) In total, projects worth USD 900 billion (approx. RMB 6.3 trillion) are said to be under implementation or at least in detailed planning. (Germany Trade and Invest (GTAI) 2019) . As there are no clear criteria that a project has to meet to be considered part of the Belt and Road Initiative, older projects are also reclassified and included in the overall figures. (Goodman and Hillman 2019) .

Much of the BRI literature refers to the global expansion of new trade routes, driven by massive investments in freight and airports, rail and high-speed rail, power plants and roads. Masood assumes an estimated sum of over one trillion. USD (approx. 7 trillion RMB) that the Chinese government is investing in BRI, or that includes "BRI-labelled" projects, and speaks of the largest infrastructure project since the Marshall Plan (Masood 2019, p. 25) . At least six new trade routes will be promoted, four of which will run over land and two through the sea. The two routes of the "Maritime Silk Road" lead from southern China via Malaysia, Sri Lanka and India to Africa and southern Europe. Here, Chinese companies are investing primarily in seaports, airports and cargo handling centres along the routes. At the same time, overland trade routes are being realised through the construction of new train routes and motorways, power plants and inland ports from China to Southeast, South and Central Asia, as well as to Eastern and Central Europe. (Winter 2016) . Meanwhile, BRI is also targeting regions in Australia and Latin America.

President Xi stresses that besides developing new trade routes, science is an important pillar of the BRI (Roussi 2019) . However, it is difficult to find concrete BRI R&I-relevant projects and assess their impact due to the lack of meaningful documents (see also BRI aspects in chapter 6.1). The EU is not an official partner of the BRI. Nevertheless, there are individual projects in Europe that are classified as BRI, the majority of which are infrastructure projects. (Jung-Grimm 2019) .

2.2.5 16+1 or 17+1 cooperation initiative

In 2012, even before the introduction of the BRI, China established an international initiative with then 16, now 17 Central, Eastern and Southeastern European countries (Greece joined in April 2019). The "17+1 Cooperation" or "China-CEEC Cooperation" (China and Central East European Countries Cooperation) links China with twelve EU member states (Bulgaria, Estonia, Greece, Croatia, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia, Czech Republic, Hungary) and five countries that are not members of the EU (Albania, Bosnia and Herzegovina, Montenegro, Northern Macedonia, Serbia). The aim of the initiative is to cooperate on numerous topics, such as trade, investment, mobility, health and cultural exchange, as well as science, technology and education. (Cooperation between China and Central and Eastern European Countries (CEEC) 2019) . In the meantime, 17+1 and BRI activities in Europe have come together. As part of the cooperation, annual meetings with the government representatives of the 18 nations have been held since 2012. While most investments are in infrastructure, scientific cooperation includes Chinese medicine centres in Hungary, the Czech Republic and Montenegro, as well as a China-Central and Eastern Europe Institute in Budapest. (Roussi 2019) . Overall, this initiative by the Chinese government may lead to the weakening of the European Union. On the other hand, large EU countries such as Germany and France also maintain their own bilateral forms of cooperation with China. (Benner et al. 2018, p. 7) .

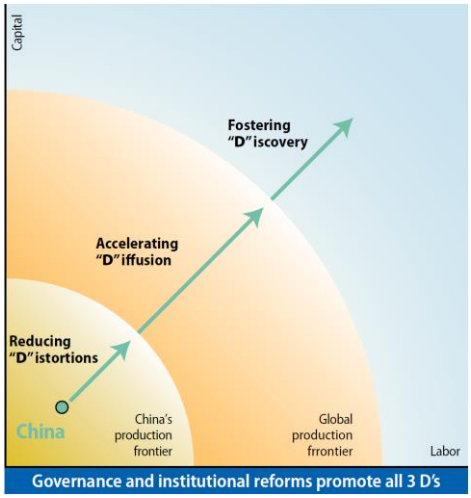
2.2.6 World Bank Study: Elaboration of a "3+6+7 Reform Agenda

The initiatives described above promote China's economic growth and drive the country's development.

However, in order to promote the economy in the long term and sustainably, China needs new drivers of growth ("drivers of growth"), which are elaborated in a recent study by the World Bank together with the Development Research Center of the State Council of China (DRC). China has a "Human Capital Index" of 0.67 and ranks 46th in the world (in 2018), according to the World Bank. (World Bank 2018) . Moreover, significantly fewer workers in China have a tertiary degree than in OECD countries. While in OECD countries on average about 37% of all workers have a university degree, in China it is only about 20%. (World Bank and Development Research Center of the State Council 2019; OECD 2019) . The proportion of academics in the workforce is also lower in China than in OECD countries. Furthermore, China faces challenges in terms of productivity growth, which has been much slower than before over the last decade. Total factor productivity, a comprehensive measure of how productively an economy uses capital and workers, is only about half as high in China as in OECD countries. (World Bank and Development Research Center of the State Council 2019) .

To counteract these developments, the World Bank and the DRC have developed the so-called "3+6+7 Reform Agenda". It aims to increase China's productivity and promote economic growth and innovation. The agenda first defines ***three*** growth drivers, the three D's: "Reducing Distortions", "Accelerating Diffusion" and "Fostering Discovery" (see Figure 4). This refers to improving the allocation of resources, diffusing advanced technologies and promoting research and innovation. What is important here is a more effective allocation of resources that is oriented towards market competition, as well as the creation of a true balance between market and state economies. Accordingly, state-owned enterprises will continue to play a major role, but they should compete on an equal footing with non-state-owned enterprises so that the most productive firms can prevail.

Figure 4: The three D's of the "3+6+7 reform agenda



Source: World Bank and Development Research Center of the State Council 2019, xix

Six strategic choices should drive the three D's and promote economic growth: (1) equal alignment of the three drivers of growth; (2) a competitive market economy; (3) a balance between government and business; (4) mutually profitable trade and investment agreements with international partners; (5) a balance between reforms to supply and demand; (6) preparation for the future impact of technological change.

Structural and institutional reforms in ***seven*** critical areas are to help address the challenges of the three D's. Here, the aim is to (1) transform industrial policy and expand market competition; (2) promote innovation and the digital economy; (3) develop human capital; (4) allocate resources effectively; (5) support regional development and inclusion; (6) promote economic globalisation and competitiveness; and (7) launch and regulate the next transformation.

The document on the "3+6+7 Reform Agenda" analyses that China is dependent on mutually profitable

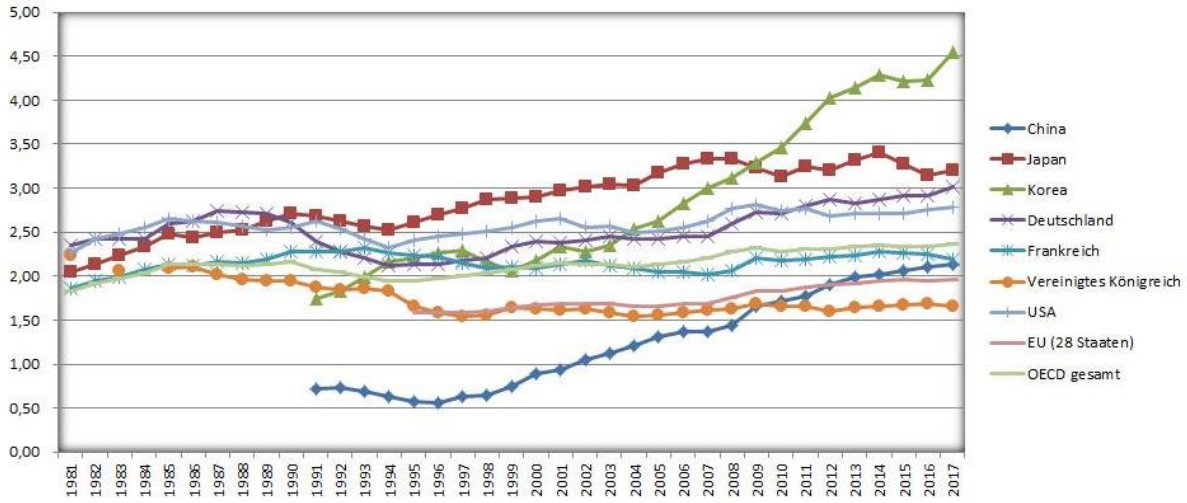
trade with international partners and should therefore make the framework conditions fair. Another highlighted point is addressing the impact of digital transformation on China's labour market and on regional and social disparity. Because of new technologies and innovations, especially AI, robotics and automation, the labour market is changing. Many jobs are at risk and workers with higher degrees are predominantly needed. This is an issue that also concerns Germany (Federal Ministry for Economic Affairs and Energy (BMWi) 2019) . The report also calls for a further international opening of China, a more horizontal industrial policy and more open cybersecurity legislation. It also recommends reducing regional disparities in China, which continue to disadvantage large sections of society. According to the authors of the study, only a market opening in China can lead to the country taking the next step in international competitiveness and economic development. (World Bank and Development Research Center of the State Council 2019) .

The recommendations from the study, in essence the "3+6+7 reform agenda", take up many demands of Western actors on China as important next steps for China's further rise. The study thus provides a basis for joint dialogue with China.

2.3 Investment in research and innovation

China's spending on R&D has risen steadily, from 0.72% of gross domestic product in 1991 to 2.13% in 2017 (Germany from 2.4% in 1991 to 3.02% in 2017) (see Figure 5). This means that China is still below the OECD average of 2.37 %, but if one looks at the absolute figures, only the USA spends more money on R&D than China (see Figure 6). The absolute figures also show the rapid catching-up process that China has started in recent decades. Japan and Germany were already overtaken 10 and 15 years ago, respectively.

Figure 5: R&D expenditure as a share of gross domestic product in % (1981-2017)

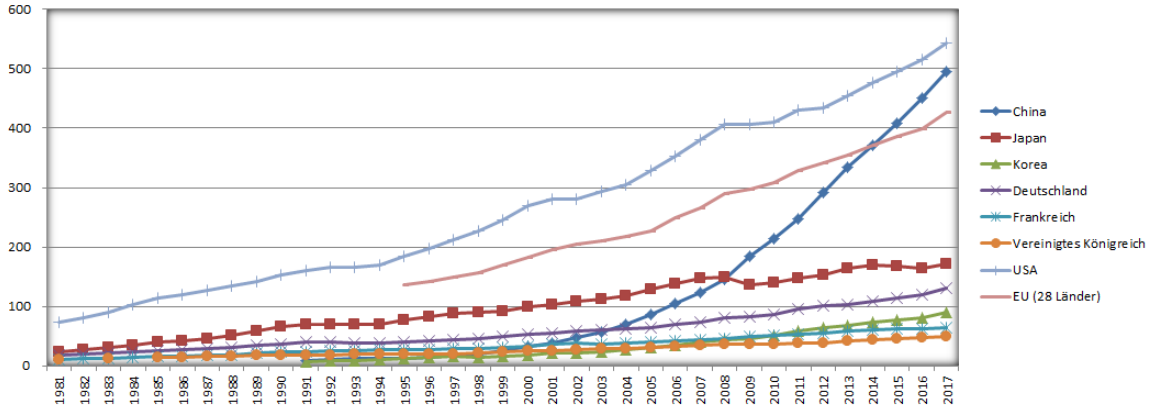


Expenditure on research and development as a percentage of GDP.

Source: own representation based

on OECD 2019b

Figure 6: Gross domestic expenditure on R&D (GERD) adjusted for purchasing power (1981-2017)[1)]

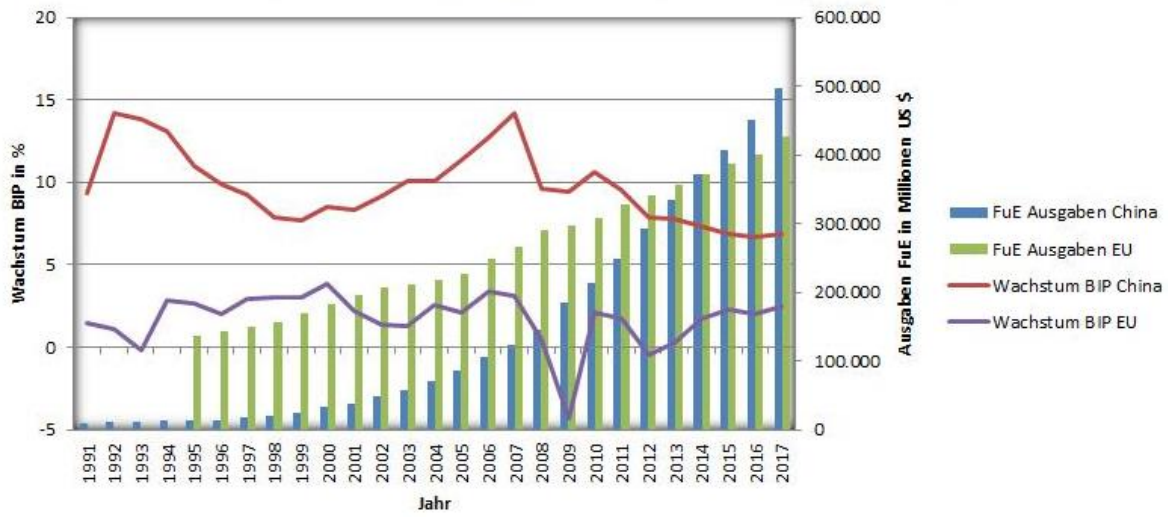


1) in billions of USD
Source: Own presentation on the basis of OECD 2019b

When collecting statistics in the field of R&D, one repeatedly comes across very different figures, especially when comparing European/Western and Chinese sources. It is not always clear from the sources themselves how the differences arise. In the following, therefore, the standardised statistics of the OECD are used as far as possible to enable comparability with Germany and the EU (the OECD also relies on data from China and these are not always reliable). (Yang 2019a)). However, some statistics on China can only be found in Chinese publications and have been included.

For 2020, China has set itself the goal of spending 2.5% of its GDP on research. The target seems ambitious, but within reach. Germany reached the 3% target in 2017 and is currently discussing a 3.5% target, which would roughly correspond to R&D spending of EUR 125 billion in 2025. (Frietsch et al. 2017) . In contrast to the consistent development and ambitious targets of Germany and China in terms of R&D intensity (i.e. R&D expenditure in relation to GDP), the EU as a whole is stagnating at around 2% (see Figure 5, p. 32). This is mainly due to the fact that, in addition to the growing R&D expenditure, GDP has also risen significantly (Publications Office of the European Union 2019, p. 59) .

Figure 7: R&D expenditure vs GDP growth rate in China and the EU (1991-2017)



Source: Own representation based on (OECD 2019b)

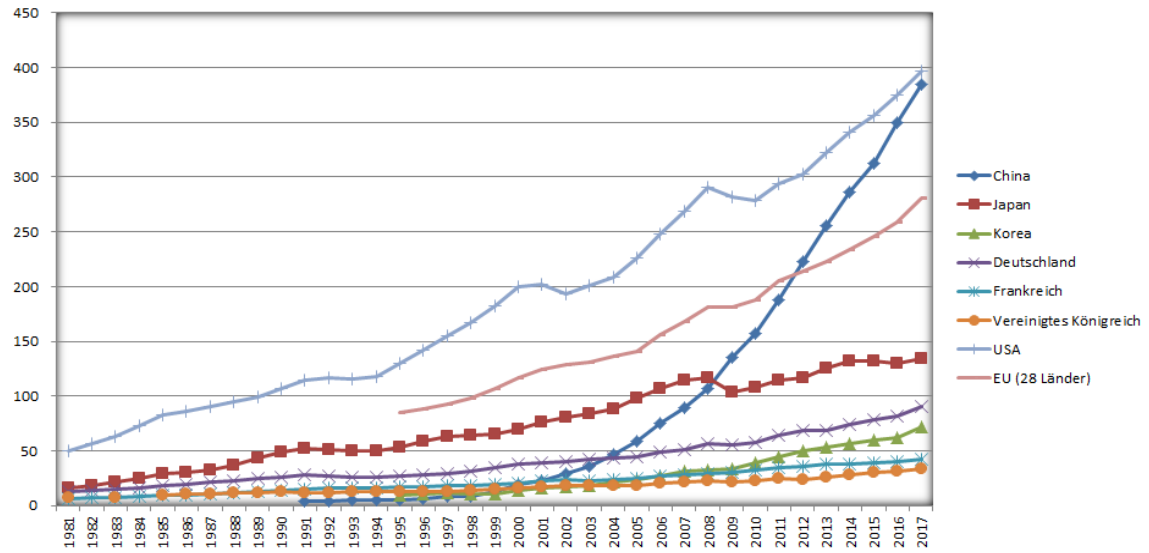
2.3.1 Sources and structure of R&D expenditure

Businesses now play a major role in China's R&D system, as they provide much of the research funding.

From the early 1990s to 2017, business R&D spending increased sharply and is now higher than in the EU (see Figure 8). In China, about 76% of research spending is currently borne by businesses (for comparison: in the US it is 64%, in Germany 66%, in the EU 57%, in the OECD 63%. (OECD 2019b).

While in Germany about 2/3 of R&D spending has been done by industry for many years, in China the share of industry has built up within 20 years and this development seems to be continuing.

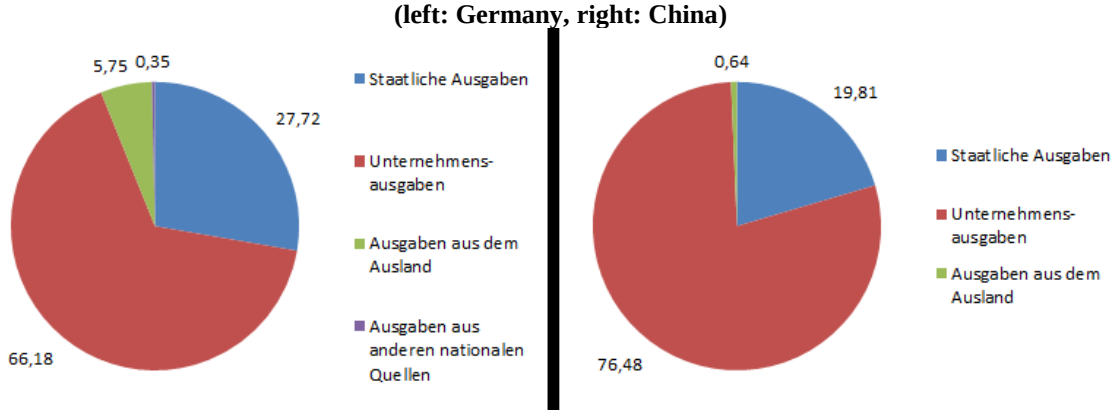
Figure 8: Business expenditure on R&D (BERD) in billion USD1) adjusted for purchasing power (1981-2017)



1) Business expenditure on R&D (BERD) does not come exclusively from businesses, but may also be financed to a small extent by government or other agencies.
Source: Own representation based on (OECD 2019b)

A direct comparison between Germany and China in research funding (Figure 9) shows that the share of government expenditure is initially higher on the German side. However, it should be noted that in China, due to the economic structure, expenditure by companies also includes expenditure by state-owned and state-related companies. This makes it difficult to compare the figures. In contrast to Germany, R&D investments from abroad are hardly relevant in China (see Figure 9 and Chapter 6).

Figure 9: Percentage distribution of R&D expenditure in Germany and China (2017)1)
(left: Germany, right: China)



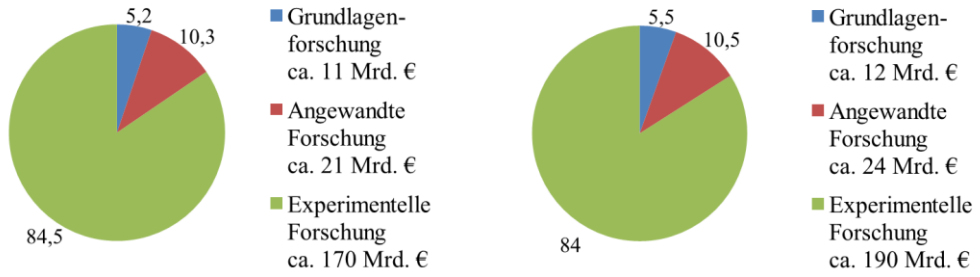
1) No data for China on "expenditure from other national sources".
Staatliche Ausgaben: Government spending, Unternehmensausgaben = Corporate spending, Ausgaben aus dem Ausland = Expenses from abroad, Ausgaben aus anderen nationalen Quellen = Expenditure from other national sources
Source: Own representation based on (OECD 2019b)

In Chinese research, a large part of the money is invested in so-called experimental development for market-oriented adaptation and implementation research. Significantly less funds flow into basic

research or so-called applied research. Based on Chinese statistics with total research expenditures of 1.76 trio. RMB (approx. EUR 220 billion) in 2017, only just under RMB 98 billion (approx. EUR 12 billion) was spent on basic research and just under RMB 185 billion (approx. EUR 24 billion) on applied research (see Figure 10). For experimental development, i.e. research very close to the commercialisation of a product, on the other hand, expenditure is higher and corresponds to almost 1.5 trillion RMB (190 billion EUR) in 2017. RMB (EUR 190 billion). This can be partly explained by the high industrial share of R&D investment, but public funders also prefer investments with quick results.

Meanwhile, China is also increasingly investing in basic research (see Figure 10). Thus, in both the MOST and the NSFC, and in Chinese R&D spending overall, even more growth can be seen in basic research in the years since 2016 (Frietsch et al. 2018a, p. 57) .

Figure 10: R&D expenditure in China by type of research in comparison 2016 and 20171)



1) According to Chinese statistics; figures in %
Grundlagenforschung = basic research, Angewandte Forschung = applied research, Experimentelle Forschung = experimental research

Source: own presentation based on data from Sun Yutao (孙玉涛) et al. 2019

Textbox 3: Explanation of terms used in the Chinese R&D system

Misunderstandings occur time and again due to the use of words in different ways or to translation interpretations:

The following terms are used in Chinese R&D statistics:

Basic research refers to experimental or theoretical research conducted to gain new knowledge about the fundamental principles of phenomena and observable facts. It is not intended for any particular or specific application or use.

Applied research refers to creative research conducted to determine the potential uses of basic research findings or to explore new methods or new approaches to achieve a predetermined goal. Applied research is primarily directed towards a specific purpose or goal.

Experimental development refers to the use of existing knowledge from basic research, applied research and practical experience to create new processes, systems and services for the creation of new products, materials and devices, as well as systematic work to significantly improve the above items that have been created and established.

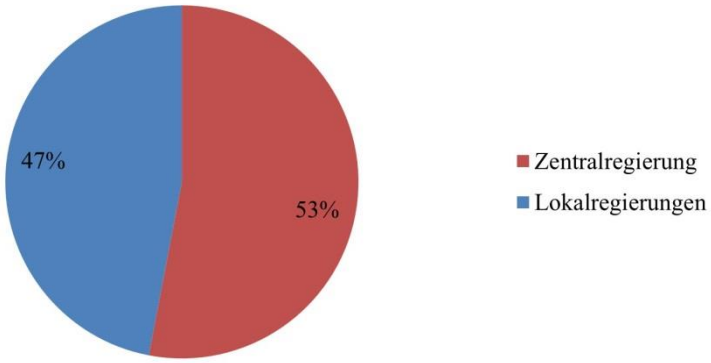
Source: Sun Yutao (孙玉涛) et al. 2019

2.3.2 Regional differences in China

Local governments play a major role in government R&D spending, i.e. the implementation of plans in China. Almost half of government spending does not come from the central government, but from provinces and cities (see Figure 11). This has an influence on which regions in China have the highest

R&D investments.

Figure 11: Distribution of public R&D expenditure among government actors (2016)[1)]



Zentralregierung = central government, Lokalregierung = local government
Source: own representation based on data from Sun Yutao (孙玉涛) et al. 2019

In general, the eastern and south-eastern provinces are more economically developed than the central, northern and western regions. The largest industries and companies are also more likely to be found in the coastal provinces, and their corporate spending on R&D further reinforces the large regional differences. Figure 12 clearly shows this difference between the provinces.

Figure 12: R&D expenditure of Chinese provinces incl. economy in 100 million RMB (2016)[1)]

1) At the provincial level, Guangdong in the south (RMB 72.26 billion, approx. EUR 9.2 billion) and Jiangsu (RMB 35.09 billion, approx. EUR 4.46 billion) and Shanghai (RMB 34.17 billion, approx. EUR 4.35 billion) in the east are in the top group for local R&D funding.
Source: Sun Yutao (孙玉涛) et al. 2019

China and especially China's coastal regions must be understood as economic variables in their own right, rather than merely as a part of the centralised system. (Sigurdson 2004, p. 7) .

The differences between China's cities are even more pronounced (see Figure 13). There, individual cities such as Shenzhen, Shanghai and Beijing stand out with their R&D spending and stand far apart from the rest of the country. The great importance of individual cities within a province is also evident.

For example, Shenzhen's R&D expenditure (with the companies located there such as Huawei, Tencent, etc.) corresponds to more than half of the total expenditure of Guangdong province.

Figure 13: Comparison of R&D expenditure of Chinese cities incl. economy in 20161)

Platzierung	Stadt	FuE Ausgaben (in 100 Millionen RMB)
1	Shenzhen	404
2	Shanghai	342
3	Beijing	286
4	Tianjin	125
5	Guangzhou	113
6	Hefei	102
7	Suzhou	95
8	Wuhan	86
9	Hangzhou	75
10	Ningbo	57
11	Nanjing	53
12	Wuhu	52
13	Chongqing	52
14	Chengdu	46
15	Wuxi	37
16	Zhuhai	35
17	Foshan	35
18	Yancheng	32
19	Wuwei	29
20	Dongguan	28
21	Zhongshan	28
22	Xi'an	27
23	Changsha	25
24	Qingdao	24
25	Changzhou	24

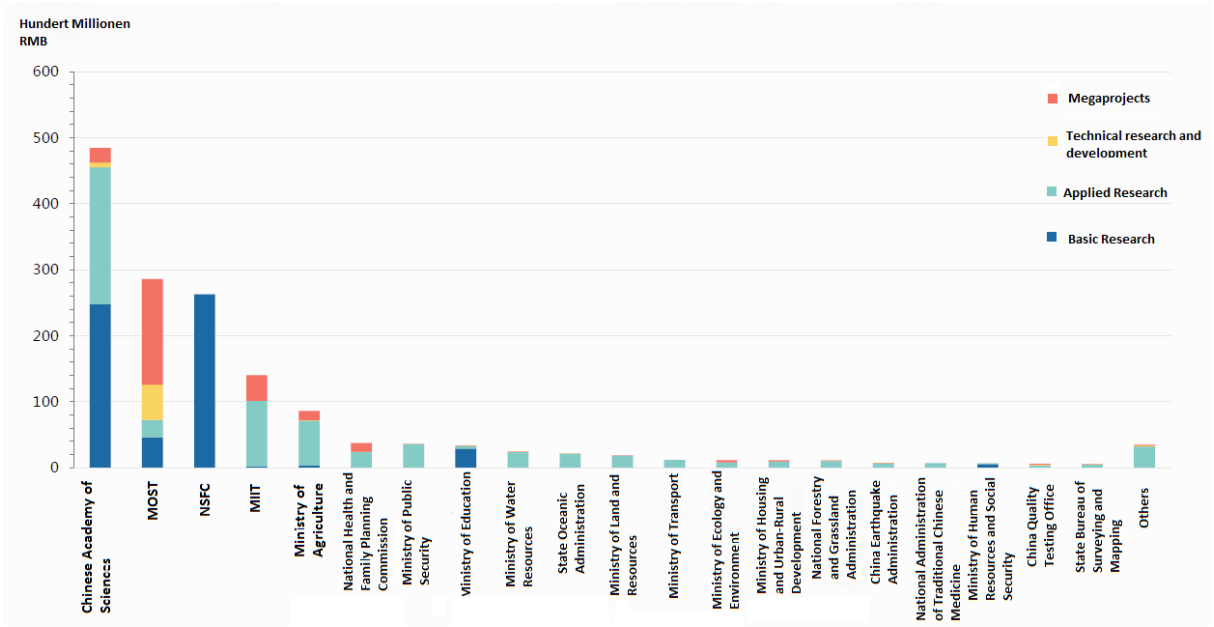
1) At the city level, Shenzhen (RMB 40.4 bn, approx. EUR 5 bn), Shanghai (RMB 34.2 bn, approx. EUR 4.3 bn) and Beijing (RMB 28.6 bn, approx. EUR 3.6 bn) have the highest allocated R&D expenditure.

Source: Sun Yutao (孙玉涛) et al. 2019

2.4 Institutions and main research fields

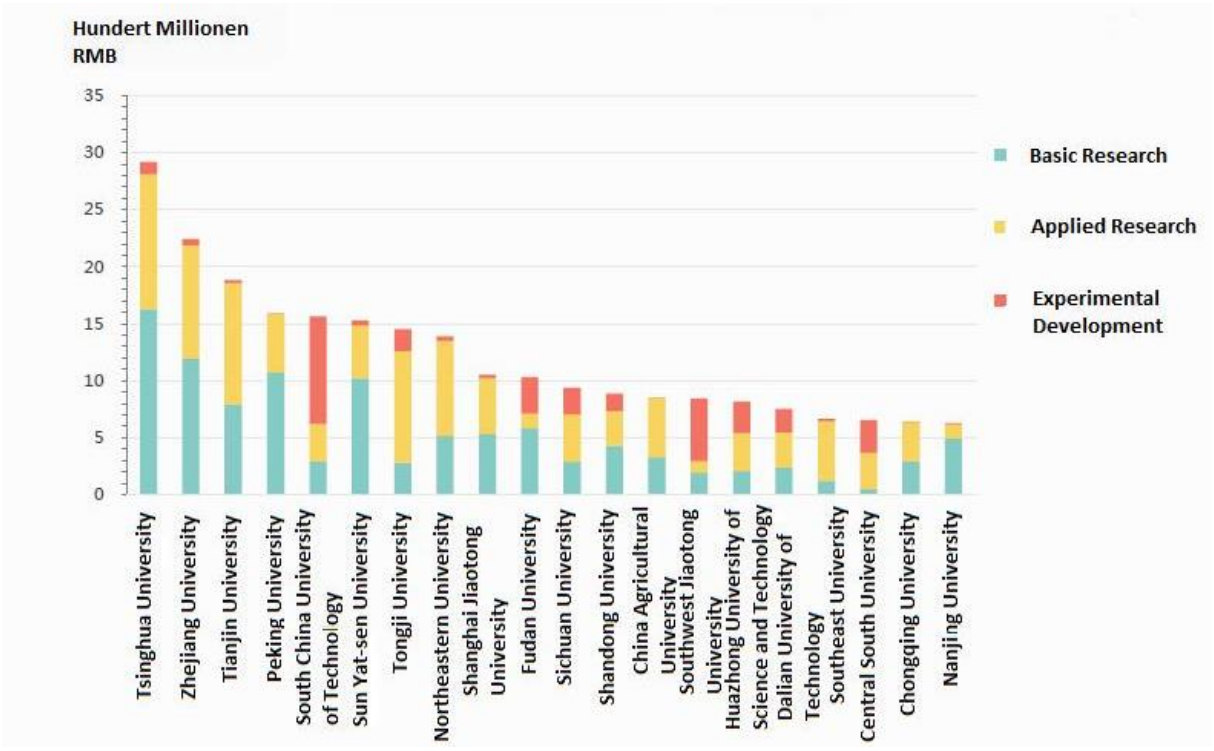
The state R&D budget is divided among various institutions. The Chinese Academy of Sciences (CAS) had by far the largest budget in 2016, with almost RMB 50 billion (approx. EUR 6.25 billion: cf. MPG EUR 1.8 billion 2017). Institutionally, it is on the same level as the ministries. The Ministry of Research MOST and the Chinese National Natural Science Foundation (NSFC) are in second and third place, each receiving almost RMB 30 billion (approx. EUR 3.7 billion, cf. DFG 2018 EUR 3.4 billion); the Ministry of Industry and Information Technology and the Ministry of Agriculture each receive around RMB 10 billion (approx. EUR 1.2 billion) (see Figure 14). All other institutions receive far less funding. Figure 14 clearly shows the importance of the so-called "megaprojects" - large-scale measures that focus on individual technologies - in China. In contrast to the other special programmes, they are shown separately and take up more than half of the MOST budget, for example. Together with the expenditure for technical research, more than 2/3 of the MOST budget is spent on more industrial policy goals.

Figure 14: Main state actors in Chinese R&D in 2016



Source: Sun Yutao (孙玉涛) et al. 2019

Figure 15: R&D funds of China's top universities in 2016



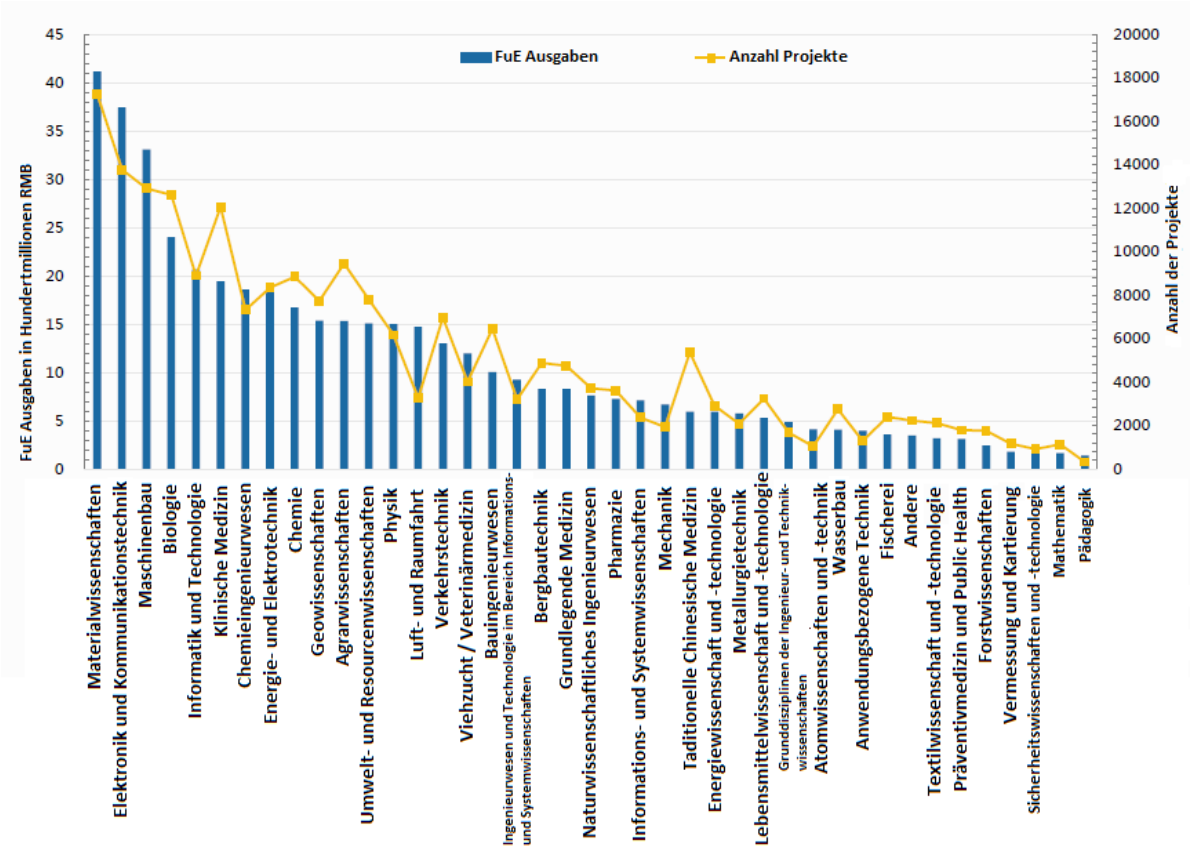
Source: Sun Yutao (孙玉涛) et al. 2019

In Chinese universities, the budget for R&D is distributed very unevenly among the many different universities. For example, the few "elite universities" such as Tsinghua University, Zhejiang University, Peking University etc. receive very generous funding, while the lesser-known universities are provided with much less money (see Figure 15). This also further contributes to the regional inequality mentioned above, as the best-funded universities are equally located in the richer and better-developed coastal

regions. The strong regional polarisation of the Chinese innovation system is thus also characterised by the location of the top universities and top companies, which are concentrated in a few locations in the coastal provinces. The top universities shown here use about half of their research budget for basic research.

The overview of the main research areas funded at the colleges and universities (see Figure 16) also shows a relatively strong specialisation in some fields considered important. The differences in the amounts allocated to the individual fields are large in some cases. The technical and natural science subjects in particular stand out. Thus, in descending order, the largest research expenditures go to materials science, electronics and communications technology, mechanical engineering, biology, computer science and technology, clinical medicine, chemical engineering, energy and electrical engineering and chemistry.

Figure 16: R&D expenditures of colleges and universities by main research areas in 2016



Source: Sun Yutao (孙玉涛) et al. 2019

2.5 Research funding

The Chinese science and research funding system has developed dynamically over the past four decades and has undergone repeated reforms. Since the beginning of the reform and opening-up policy in 1978, science and technology development has been a major goal of Chinese policy.

A leap in development took place from the 2000s onwards, as can be seen from the indicators in the chapter on the performance of the innovation system (Chapter 4). The continuous increase in research and development (R&D) expenditure over the past 20 years is proof of this. With the change in party and government leadership in 2012/2013, a decision was made to reform the science system, despite some early and visible successes (e.g. Tianhe-2 supercomputer, Chang'e lunar lander) and a good development of R&D indicators. The reason for this was the increasing criticism of the science system,

such as redundancies, inefficiencies, lack of transparency regarding ministerial and administrative responsibilities, non-transparent funding decisions and processes, unclear monitoring of results, unclear awarding and funding practices, and the risk of corruption. (DLR Project Management Agency and VDI-TZ 2015) . During the third plenary session of the 18th Central Committee of the Communist Party in November 2013, the reforms in the field of project funding and management were announced and a directive of the State Council in March 2014 set out measures for coherent project management and improved resource allocation. The coordination of research projects as well as the allocation of funds should be strengthened. Project management and project application processing were to be improved through clear guidelines. In addition, the monitoring of research projects and their funding was intensified (DLR Project Management Agency and VDI-TZ 2015) .

A visible step of the reform is the introduction of the National Science and Technology Report Services (NSTRS) since 2014. The goals of the NSTRS are more transparency about publicly funded research, the avoidance of duplication in project funding and the immediate review of research results for novelty and authenticity.

A further step was the decision to set up a professional project management system with eight largely subject-specific funding agencies that administer project funding in a standardised manner using a newly set up integrated central administration platform and software for science and technology. In addition, there is a standardised review and programme-specific monitoring of research and development projects (interviews 2019).

Textbox 4: Official project promoters for research funding in China

- China Rural Technology Development Center:
  (中国农村技术开发中心) http://www.crtdc.org.cn
- China 21 Century Yicheng Management Center
  (中国21世纪议程管理中心) http://www.acca21.org.cn
- China National Center for Biotechnology Development
  (中国生物技术发展中心) http://www.cncbd.org.cn
- High-Tech Research and Development Center, Ministry of Science and Technology
  (科学技术部高技术研究发展中心) http://www.htrdc.com
- Development Centre for Science and Technology, Ministry of Agriculture
  (农业农村部科技发展中心) http://www.nybkjfzzx.cn
- Development Center for Medical Science and Technology, National Health Commission
  (国家卫生计生委医药卫生科技发展研究中心) http://www.dcmst.org.cn
- Industry Development and Promotion Center, Ministry of Industry and Information Technology（工业和信息化部产业发展促进中心) http://www.idpc.org.cn
- China Science and Technology Exchange Center（中国科学技术交流中心) http://cstec.org.cn

This reform process was accompanied by a large number of advisory visits, including international ones, by Chinese delegations. In addition, the reform process was based on analyses of leading project funding structures (including the European Commission, UK, USA). Germany's funding system was also considered, and delegations visited German actors (including, for example, DLR-PT). Aspects of the EU Commission's administrative system for the EU Framework Programmes seem to have had an influence on the reform: For example, the NSTRS is similar to the EU CORDA system and the thematic project management agencies, which report directly to the government, are similar to the "Executive Agencies". The new system has now been in place for about two years, and in addition to the NSTRS and the establishment of the Chinese project management agencies, the first results of the reform can be

read, which are presented on a website newly set up for this purpose. The source for the following information on the research funding system is the National Science and Technology Information System of the Public Service Platform (SCIPING (科塔学术) 2019) . The site is available in Chinese.

Since 2016, 2,665 projects have been funded by MOST, of which 90 are still in the process of approval (as of July 2019).

2016

In 2016, a total of 42 specialised programmes were established and 1,173 approved projects were published. An interesting special form of funding in China is the approval of 70 projects without a specific funding amount and duration. This is only awarded and paid out after a review after 2 years.

The total funding of the 1,103 projects with a clearly identified amount is RMB 27.85 billion (approx. EUR 3.5 billion). The average funding for a single project is RMB 25.25 million (approximately EUR 3.3 million). and the maximum individual funding is RMB 433 million (approximately EUR 56 million), with a minimum of RMB 560,000 (approximately EUR 72,000). (SCIPING (科塔学术) 2019) .

2017

In 2017, 44 specialised programmes were established. Major new programmes included funding for "Large Oil and Gas Fields" and "Intelligent Robots" as "Major S&T Projects". Here, too, there are directly funded projects and projects with follow-up funding. 1,185 projects were approved, 20 of which are designated as "targeted lead projects". Of the 1,185 projects, 18 projects are designated without funding quotas and duration. The total funding amounts to approx. 23.73 billion RMB (approx. 2.9 billion EUR, cf. BMBF project funding 3.9 billion EUR), the average funding amount for an individual project is 20.33 million RMB (approx. 2.5 million EUR) and the maximum individual funding amounts to 117.6 million RMB (14.7 million EUR), with a minimum of 1.51 million RMB (approx. 188,000 EUR). (SCIPING (科塔学术) 2019) .

Indicators for the evaluation of research funding

A good measurable indicator for the efficiency of a funding administration is the processing time of applications. This time between application submission and application approval ("time-to-grant") must be defined as the basis for assessment. In the EU Commission's regulation, it is the time that elapses between the submission of the application and the day on which the contract or grant notification is sent to the applicants. This time period can be influenced by various things: whether individual applicants or consortia are funded; whether national or international funding is provided; whether there is intensive consultation prior to submission; whether there is an informal outline phase prior to formal submission; whether there is internal or external evaluation; whether the end time is defined by the information on the funding decision or the actual sending of the formal decision, and other things. In addition to these influences resulting from the type of programme, there are also influences of a budgetary nature (e.g. the timing of the government's budget decision influences the timing of new approvals), of a regulatory nature (e.g. changes to European state aid rules must be implemented in national regulations) or of a political nature (country cooperation is suspended as a result of upheavals).

A conflict of goals arises: on the one hand, the shortest possible processing time is desired so that research is closely linked to the proposal idea in terms of time, which is very important, for example, when involving the private sector and in subject areas with short innovation cycles. On the other hand, evaluation and approval should be fair and evidence-based, and contracts should be legally sound. According to the Chinese Science and Technology Exchange Center (CSTEC), this "time-to-grant" period was set at 120 days in China as part of the reform (Interview 2019). On another visible result of the reform, the national research funding information platform, actual "time-to-grant" times can be read off (SCIPING (科塔学术) 2019) . The site does not allow for a statistical analysis of all projects. Our

own evaluation of 20 randomly selected individual cases of national project funding in the field of biotechnology revealed "time-to-grant" times of four to five months. This processing time corresponds to the planned 120 days (SCIPING (科塔学术) 2019) .

As part of the optimisation of the administration for the HORIZON 2020 (H2020) research framework programme, the EU Commission has stipulated that 180 days after the submission of an application or a bid, the decision on funding must have been made and the applicant should receive a corresponding decision or contract. An own evaluation of six different H2020 programmes of the EU Commission shows that although there are differences in the individual programmes, they are relatively small. On average, processing takes seven to eight months (see Table 1). All the programmes considered thus exceed the target value.

Table 1: Time period between the submission date for an H2020 notice and the grant notification/contract

Pillar	Time-to-grant (in days) (Arith. Mean)	Time-to-grant (in days) (median)
EC (European Commission)	214	**210**
Euratom (Supplement to H2020)	254	**238**
Excellent Science (Scientific Excellence)	264	**232**
Industrial Leadership (Leading role of industry)	213	**213**
Science with and for Society (SwafS) (Science with and for Society)	241	**232**
Societal Challenges (Societal Challenges)	212	**232**
Spreading excellence and widening participation (Spreading excellence and widening participation)	**226**	**233**

Source: Own evaluation and presentation based on the CORDA database, European Commission 2019 (query June 2019)

Similar to China, project funding in Germany is diverse and, as in China before the reform, is organised by different ministries with different subordinate institutions. It addresses different target groups such as individual SMEs, individual universities or research organisations, alliances and clusters. It funds everything from market-oriented developments to basic research and uses adapted evaluation and administrative procedures for this purpose, each of which has its own application mechanisms and processing times. An overview of the processing times in the individual funding areas is not publicly available.

Our own evaluation of accessible data on the PROFI database was possible for 380 projects with a start date in the four years 2015-2018 in international cooperation (our own evaluation of the PROFI database, 2019). The time between the submission date stated in the respective funding announcement and the date on which the decision was sent to the funded projects was read out. This small project dataset does not claim to represent broader German funding practice. For these projects, which usually have a two-stage procedure with an outline phase and an application phase and in many cases undergo bilateral coordination with foreign partners, the mean value over the years 2015-2018 is 358 days processing time between outline submission and funding decision. Table 2 shows visible differences in processing

times between the individual years. It is not possible to discuss the causes within the scope of this study.

Table 2: Duration between the submission deadline for an international announcement by the BMBF and the funding decision/contract

2015	156
2016	379
2017	420
2018	244
Overall result	**358**

Source: Own evaluation and presentation based on the PROFI database (query June 2019)

The authors have another example of processing times from NRW. The state of NRW achieves an arithmetic mean processing time of around 225 days in the NRW innovation funding programme (internal communication).

The ZIM programme (Central Innovation Programme for SMEs) of the BMWi states a maximum of 3 months as the standard processing time on its website. (Central Innovation Programme for SMEs (ZIM) 2018) and, according to oral information, is within this time frame in 90 % of cases (interview 2019). The current evaluation of the ZIM programme indicates a high level of satisfaction with the programme on the part of the applicants. (Kaufmann 2019) .

In the EUROSTARS programme, a funding programme for SMEs between European states (only the programmes of the EU Commission are shown in Table 1), which is funded in Germany by the BMBF, the definition applies:

"Time-to-contract is the time elapsed between the cut-off date and the date of notification of the grant decision from the NFB to the participant, or the date of signature of the grant agreement." (Shaton et al. 2017, p. 80)

The agreed target is a "time-to-contract" of 7 months or less. Averaging across all participating countries and the years since 2014, this target is usually achieved. In 2018, the time-to-contract value averaged across all countries was 6.9 months for the first cut-off date (February 2018) and 5.9 months for the second cut-off date (September 2018) (oral communication DLR-PT). In the course of the preparations for the EUROSTARS 3 programme, the shortening of the time-to-contract is being discussed.

Economically, it makes sense not to invest more resources (e.g. the total number of working hours of scientists in the preparation of applications) in the application process than the funding itself promises in total. Therefore, another indicator of the efficiency of research funding is the accuracy of a funding announcement, which is made visible by the success rate (number of valid applications submitted vs. successful applications). This should guarantee a meaningful relationship between the effort required to submit a proposal and the chance of success. In 2017, the DFG had an average success rate of 30%. (Kroll 2019) . For ZIM, a success rate of 65 % is given. (Kaufmann 2019) This is explained by the high continuity of the programme and the intensive advisory services provided prior to application. The advice leads to fewer applications not eligible for funding being submitted (interview 2019). In China, there is no publicly available data on these indicators (according to oral communication in China, the rate varies greatly from programme to programme). For German project funding, no data is publicly available in a collected form. The EU Commission publishes these figures, which diverge greatly from programme to programme.

The effectiveness of the funding can be determined by "output" variables (what was done: workshops, publications, patent applications, etc.), "outcome" variables (what came out: citations of publications,

use of patents, etc.) and, in the best case, "impact" variables (what did it achieve: change of perspective through publication, new products or social innovations based on research, patents, etc.). To describe effectiveness, a continuous evaluation and monitoring mechanism is needed, which is announced and also partly implemented in China (National Center for Science and Technology Evaluation of China 2019) but is not yet documented in a publicly comprehensible way.

The evaluation of the ZIM programme 2019 examines the effectiveness of the programme: "*From the econometric analyses carried out, there are also consistently positive effects of the programme* in *terms of R&D expenditure, R&D employment and R&D employment intensity*" (Peter 2019, p. 8).

A summary of the impact of direct research funding, differentiated according to the individual programmes in Germany, is not publicly available.

The budget distribution indicates that public project funding is a relevant innovation economic instrument in Germany.

"*However, with regard to the target group of small and medium-sized enterprises, which have so far conducted little or no R&D, great potential is seen in the area of direct project funding. This applies both to technology-specific funding (specialised programmes) and to funding open to all technologies (ZIM).“* (Frietsch et al. 2017, p. 141)

In Germany, federal R&D expenditure amounted to approximately EUR 17 billion in 2017, of which the BMBF manages approximately 60 % (BMBF, Federal Report on Research and Innovation, 2018) (2019 budget: EUR 18.3 billion). This R&D expenditure is divided between project funding (mainly BMBF) and departmental research (other ministries) with about EUR 8.3 billion (2017) and institutional funding with about EUR 7.7 billion (2017). In 2017, the BMBF financed R&D with approximately €3.9 billion in project funding directly through its own contractually bound project executing agencies, primarily for politically relevant topics and cooperation projects between the private sector and academic research. To this must be added another approx. 3.4 billion euros, which was allocated via the German Research Foundation (DFG) through competitive project funding, primarily for academic research projects (91.3 % at universities). Project funding thus accounts for about €7 billion of federal R&D expenditure. For the Agency for Leap Innovations, which is currently in the planning stage, an annual budget of EUR 100 million is currently planned (BMBF, 2019: press release), with a term of ten years and a budget of around EUR 1 billion. The tax-based R&D funding, which is also in the planning stage, assumes a volume of around EUR 5 billion for a planned term of twelve years. This is the amount of the tax losses resulting from the BMBF's support (Master 2019) .

An essential aspect of the reform in China is the digital transformation of the control, processing and administrative procedures. The use of AI, e.g. in the search for experts, is being tested. According to experts, China is dependent on the digital transformation of its own funding system in view of the growing volume of funding applications (225,000 in 2018) in order to be able to review all applications in the future (Kooperation International 2019). The European Research Council (ERC) also pointed out the importance of these tools in mid-2019 when publishing the new programme. And Norway is also examining the use of machine learning in project funding:

"Other countries are following China's lead. Last month, the Research Council of Norway started using natural-language processing to cluster about 3,000 proposals into groups and match them to the best reviewer panels, says Thomas Hansteen, an adviser to the council ." (Cyranoski 2019, p. 317)

2.6 Public Innovative Procurement

An examination of the Chinese instruments for implementing research and innovation shows that different types of financing are used in parallel, especially for projects of strategic importance, such as the "National S&T Major Projects". But also in other, central and regional/local approaches, different types of financing are flexibly used side by side and in a complementary manner in China, including

public procurement of innovative products and services. In this context, the boundaries between fiscal support, (concessionary) loans, subsidies, public procurement and research funding from central or regional/local sources are difficult to distinguish for outsiders and also for Chinese actors (Interview 2019).

Innovative public procurement is understood to be an innovative procurement process with the goals of external innovation promotion in the economy on the one hand and the procurement of innovative solutions on the other. (Schaupp and Eßig 2018) . China has been using the instrument of public procurement to promote innovation since 2006 at the latest. This development began with the National Medium-and-Long-Term Program for Science and Technology Development (MLP 2006-2020) for the targeted support of innovation processes. To this end, catalogues of certified innovative products and services were initially developed by the Ministry of Research and the Ministry of Finance, for example, which public agencies can draw on. (Edquist et al. 2015) . In the meantime, procurement as part of a mixed financing focuses on programmes of strategic importance. On the one hand, innovative public procurement in China significantly promotes new technology development. On the other hand, the framework conditions and the input-output relationship remain unclear, making it difficult to assess the actual significance. (Edquist et al. 2015) .

The potential of innovation demand through innovation-oriented public procurement is stated to be large in Germany: *"More realistic is rather the assumption of a consolidated innovation-relevant share of the procurement volume between 10 - 15 %, i.e. with a total public procurement volume of approx. 350 billion EUR per year, a volume of approx. 35 to 50 billion EUR"* (Schaupp and Eßig 2018, p. 10). This is a relevant value in relation to the total expenditure on research and development according to the Federal Research and Development Report of EUR 92.2 billion (2016). (Federal Ministry of Education and Research (BMBF) 2018a) . However, this type of innovation promotion is not yet firmly anchored in Germany: *"Despite enormous potential and 30 years of political debate on this topic in Germany, innovation-oriented public procurement has not yet been able to emerge from the stage of being a 'beacon of hope for research and innovation policy'"* (statement by Jakob Edler, Professor at the University of Manchester and Director of the Fraunhofer Institute for Systems and Innovation Research). (DLR Project Management Agency 2016, p. 7) . The OECD published a broader analysis of innovative public procurement in 2017 - without China - and came to the following conclusion for Germany:

"It is extremely difficult to set quantitative targets. There is no survey about the amount of innovative procurements in Germany. However, a study to investigate possibilities to survey the most relevant statistical data was launched." (OECD 2017, P. 116)

The applicable legal framework for the awarding of public contracts (Functioning of the European Union TFEU and Directive 2014/24/EU as well as Part 4 of the Act against Restraints of Competition (GWB) and the Public Procurement Ordinance (VgV) provides the opportunity for innovative procurement. The requirement of economic efficiency and economy also includes the consideration of innovative criteria. (Schaupp and Eßig 2018) .

In Germany, too, IPP is viewed positively: *"Innovative public procurement is not an instrument in itself that you take in isolation sometimes and sometimes not, but it is a culture, an inner attitude, a culture of innovation in the institutions, so to speak"* (statement by Susanne Kurz, Competence Centre for Innovative Procurement KOINNO of the Federal Ministry for Economic Affairs and Energy (BMWi) in the BME German Association of Materials Management, Purchasing and Logistics).) (DLR Project Management Agency 2016, p. 10) .

"The potential of innovation demand through innovation-oriented public procurement is enormous. In Europe, annual expenditure on public procurement is around 17 to 19 percent of GDP (2014), while the German share would be slightly lower at around 10-15 % with an estimated annual procurement volume of 300 billion euros. If only one percent of the procurement volume could be used for new products and services, an innovation impulse of 3 billion euros would be created in Germany. This is

more than the federal and state governments provide annually in funding for research and innovation (R&D) to companies (approx. 2.1 billion euros).“ (DLR Project Management Agency 2016, p. 4)

"Other countries, such as the USA or Asian countries, are taking a more strategic approach to implementing innovative public procurement than many European countries, including Germany.“ (DLR Project Management Agency 2016, p. 16)

Two complementary phases of IPM in the innovation cycle are defined by the EU in Horizon 2020 and funded accordingly (DLR Project Management Agency 2016) . They also correspond to the names of the funding instruments in H2020 for innovative public procurement:

- Pre-Commercial Procurement (PCP): Purchasing of research and development services in the pre-commercial phase for the procurement of non-marketable solutions or existing solutions that still have inaccessibility - the so-called "pre-commercial procurement". (DLR Project Management Agency 2016) .
- Public Procurement of Innovative Solutions (PPI): Buyers act as first adopters in the market introduction phase of solutions with novel features - the so-called "awarding of public contracts for innovative products and services". (DLR Project Management Agency 2016) .

The data in China do not allow a clear assignment to these two forms. China also uses comparable instruments in combination with each other and complementary to other instruments, e.g. in the promotion of megaprojects.

Example of PCP: "Mega Projects

The National S&T Major Projects (NMP) (often referred to as megaprojects) are seen in China as large and ambitious research programmes for China's development. 16 projects were presented in 2006 as part of the MLP 2006-2020, ten of which had civilian objectives (see Table 3).

Table 3: Megaprojects with civilian goals

No.	Abbreviation of the NMP	Responsible Ministry	Medium (EUR/RMB)	Projects
1	Core Devices, Chips and Software (ICT Key Technology, Chips and Software)	Ministry of Industry and Information Technology (MIIT)	3.6 billion EUR (approx. 28.8 billion RMB)	**502**
2	Large Scale Integrated Circuit Manufacturing Equipment.	Beijing and Shanghai Governments (Governments in Beijing and Shanghai)	3.8 billion EUR (approx. 30.4 billion RMB)	**171**
3	New Generation Wireless Communication Network	Ministry of Industry and Information Technology (MIIT)	1.4 billion EUR (approx. 11.2 billion RMB)	**690**
4	Numerically-controlled machine (Numerically controlled machine)	Ministry of Industry and Information Technology (MIIT)	1.5 billion EUR (approx. 12 billion RMB)	**595**
5	Large Oil and Gas Fields Development	National Energy Administration	3.8 billion EUR (approx. 30.4 billion RMB)	**210**
6	Large-scale Nuclear Power Plant	National Energy Administration	EUR 1.7 bn (approx. MRB 13.6 bn)	**201**
7	Water Pollution Control (control of water pollution)	Ministry of Ecological Environment & Ministry of Housing and Urban-Rural Development	1.3 billion EUR (approx. 10.4 billion RMB)	**553**

8	Genetically Modified Organisms (GMOs)	Ministry of Agriculture (MOA)	1.2 billion EUR (approx. 9.6 billion RMB)	**872**
9	Major New Drugs Innovation Development (New Drug Developments)	National Health Commission	2.3 billion EUR (approx. 18.4 billion RMB)	**2029**
10	Major Infectious Disease Control (control of serious infectious diseases)	National Health Commission	1.0 billion EUR (approx. 8 billion RMB)	**387**
Total			**21.6 bn**	**6210**

Source: Own representation based on Chen (2019)

The projects in the overview aim to develop essential technologies and products to develop China as an innovation hub. They target solutions to challenges facing the country (e.g. 5 to 10), but also to perceived strategic technology gaps (1 to 4). Project progress is poorly documented and only after the reform of the research system since 2014 and the incorporation of projects into the normal research funding system are regular and systematic reviews carried out. These are understood more as advice for the government, but not as a form of accountability that examines the input-output ratio. The results are not publicly available (interview 2019). It is reported that in the period 2012-2015, approximately EUR 9.9 billion was invested by the central government for the ten civil projects, which was further complemented by investments from local agencies and companies amounting to approximately EUR 11.7 billion. These investments are said to have stimulated an output of approx. 181 billion EUR, employed approx. 240,000 scientists and enabled approx. 11,000 patents. (Main Office of the Ministry of Science and Technology (科学技术部重大专项办公室) et al. 2017) . There is no list of which shares of the funding of the mega-projects are allocated to research project funding and which shares are allocated to procurement. According to the "Management Regulations of (Civilian) National Science & Technology Mega Projects", the individual projects are assigned to one of three groups:

- "Directionally-entrusted" applications (定向委托, directional applications): In these projects, the main actor/project leader is determined, usually a state enterprise or a ministry subordinate institution, which is then tasked with the project set-up and consortium composition. It is a deliberately top-down approach. It can be assumed that this is where the budget- and planning-open projects mentioned under MOST project funding are located, and that substantial shares are financed here as procurement.
- "Directionally-selected" applications (定向择优, applications with directional selection): Here, the project management and the consortium are put together from the applicants after an open application phase following an initial individual application evaluation. The evaluation committee has the responsibility to set the professional priorities. This assembled consortium must then agree on a project proposal, which in turn is evaluated.
- "Openly-selected" applications（公开择优, openly selected applications): Here, a consortium applies for a tender in an open application process with its own technical approach. After two rounds of evaluation, the best/priced applications are selected (Main Unit of the Ministry of Science and Technology (科学技术部重大专项办公室) et al. 2017) . This procedure also corresponds at least in part to a procurement process.

Applicants must fulfil several criteria: They must be Chinese citizens supported (financially and politically) by the respective local/municipal government, they must also provide their own budget and have sufficient experience in the funded thematic field. Preference is given to partnerships between universities and industry partners. In some cases, international participation is desired in the announcement, but no such cases are documented. However, mega-projects are often carried out with international components or with subcontractors.

The budget of mega projects can be divided into direct and indirect costs, which apply to regular funding and lagging funding (Ministry of Finance（中华人民共和国财政部）; Ministry of Science and Technology（科技部）; National Development and Reform Commission (发改委) 2017).

Example of PPI: public procurement of e-bus fleets in Chinese municipalities

Although e-buses are more expensive than diesel buses in China, the charging infrastructure had to be built and optimised, and the technology is still under development, several cities in China have decided to convert their bus fleets to electric operation. Shenzhen is one of the pioneers and completed the conversion in 2018. In doing so, the decision to make this municipal innovative procurement was supported by subsidies of 50% per bus from the regional and central government (Keagan 2018) . This subsidised public procurement is the result of a long development process that started with research on electric propulsion in the 2000s and then evolved into a multi-stakeholder programme over almost 20 years:

"The most systemic policy measure is the Energysaving and New Energy Vehicles Demonstration, Promotion and Application Program ([...] 'the NEV program'), which aims to create lead markets for NEVs in selected cities.“ (Edquist et al. 2015, p. 184)

This development and almost parallel procurement, driven among other things by the desire for better air quality, had an important effect in the further development of the technology:

"Each year, we purchase buses with a longer range and higher specifications for less money. EV technology advances fast and maintenance is easier than with combustion engines,' says Li Hong, warehouse manager of e-buses in Shanghai." (Aldama 2019)

The Chinese government apparently sees its goals achieved and is currently reducing subsidies in response to technology development and cost reductions.

"Following this growth phase, the central government has now reduced subsidies for purchasing electric buses by 20 % and the subsidy will be reduced further year-on-year until 2020. (International Association of Public Transport (UITP) 2017, p. 12)

Public procurement has contributed to technology development in China, allowing rapid development steps and Chinese bus suppliers to become global market players:

"In 2001, China identified electric vehicles (EV) as a major technology. Sixteen years later, Shenzhen company BYD has become the world's biggest EV maker, and a crop of start-ups including WM Motor, Xpeng Motors and the US-listed NIO have joined the race with funding from some of the country's biggest tech companies and property developers." (Soo and Deng 2019)

2.7 Regulations

The forms of regulation that influence an innovation system are diverse. Because they came up in the public discussion on the competitive situation between Germany and China and in the interviews for this study, only exemplary topics are addressed here: Data protection, sanctions lists, underregulation and technical norms and standards.

2.7.1 Data protection

The future of the innovation economy will be determined, among other things, by access to and use of data, and here above all by personal data. The regulation of this follows different standards worldwide, which leads to competitive differences in the development of new products, applications and services. Harmonisation and a common understanding are necessary.

In China, the Cyber Security Law (CSL) came into force on 1 June 2017. It regulates data protection, IT security and conduct on the internet and thus contains similar content to the European General Data

Protection Regulation (GDPR). However, the two laws differ considerably in their focus. While the European law deals primarily with citizens' privacy rights, China is primarily concerned with maintaining network sovereignty and national security in China. (Kessler and Blöchl 2018) . The law is not to be confused with China's Great Firewall, which controls external information on its way into the country. The CSL, on the other hand, primarily controls information leaving the country. (Feng 2019) . Through the Cyberspace Administration of China (CAC), the government wants to maintain or gain control over important technologies, infrastructure and information systems. (Asia-Pacific Committee of German Business (APA) 2017) . The CSL represents the "*backbone of a new vision of the Internet by the Chinese leadership*". (Pattloch 2018, p. 1) .

According to several experts, the CSL is not clearly formulated and has a lot of room for interpretation with several broad terms (for example, "critical network infrastructure") (Asia-Pacific Committee of German Business (APA) 2017; Pattloch 2018, 2017) . The law enables state intervention in IT and communication systems and is a "*major challenge for foreign companies*" - many European companies are also affected. (Asia-Pacific Committee of German Business (APA) 2017, p. 1) .

Important key points of the law and its possible effects are as follows:

- Network operators: depending on the interpretation of the CSL, companies using or operating data processing systems in China may be required to comply with certain network security standards (for example, setting up internal security systems or employing IT security officers) (Asia-Pacific Committee of German Business (APA) 2017) .
- Local data storage and data exports: All personal data and all "important business data" must be stored on Chinese servers and may only be transferred abroad after a security check and under certain conditions (Pattloch 2018). For internationally active companies, additional costs can arise here, among other things because online maintenance or monitoring processes can no longer take place from a location outside China. (Asia-Pacific Committee of German Business (APA) 2017) .
- Critical infrastructure: In addition to the explicitly mentioned sectors of energy, finance, communications, public services, transport and water supply, all sectors that *"may threaten China's national security, economy or public interest"* also count as critical infrastructure (Asia-Pacific Committee of German Business (APA) 2017, p. 2) . Affected companies must, for example, sign security and non-disclosure agreements with suppliers or undergo separate security audits. In addition, all network products and services must be subjected to a security audit by the authorities, the exact extent of which is not yet known. Experts fear that sensitive business data (for example, source codes and algorithms) will also have to be disclosed.
- Use of VPNs (Virtual Private Networks): In addition to the disclosure of data, only encryption techniques that have been approved by the Chinese government are permitted. This will also make it more difficult to use non-Chinese VPNs. If the regulation is implemented across the board, it would have a dramatic impact on foreign companies, researchers and individuals who rely on free access to online data and online communication (Asia-Pacific Committee of German Business (APA) 2017; Specht 2018) . Without protected VPN tunnels, companies would have to encrypt each document separately, which is expensive and time-consuming. (Specht 2018) .
- Additional implications: The broad scope for interpretation allows for incorrect or arbitrary interpretation of the CSL from a European perspective and thus creates uncertainty for foreign companies. Furthermore, the increased safety standards may have a negative impact on the import of technical goods, which could contribute to a competitive imbalance (Asia-Pacific Committee of German Business (APA) 2017) . Overall, however, it remains difficult to assess the consequences of the CSL due to the vague wording. (Pattloch 2018; German-Chinese

Platform Innovation 2019). . We will have to wait and see how it is implemented in the provinces.

In parallel, Europe developed the General Data Protection Regulation (GDPR). This sets standards for data use with extraterritorial validity. With the GDPR, the EU has created an instrument that has not only become a model for legal measures in other countries within a very short time, but is already being used voluntarily as a standard worldwide due to its broad regulations on applicability to international companies (Interview 2019). In the USA, for example, the creation of a federal law on data protection is being discussed, after California led the way with a regulation based on the GDPR, the California Consumer Privacy Act (CCPA). (Wakabayashi 2018) . Japan has also been talking about aligning data protection regulations in parallel with the trade agreement with the EU. The Japanese Act on the Protection of Personal Information has been aligned with the GDPR in many respects, so that the EU and Japan have confirmed to each other that their data protection regimes correspond to their own legislations to the extent that personal data can flow freely between the EU and Japan (Interview, 2019). The same process is underway in South Korea, which is negotiating with the EU on the mutual recognition of an adequate level of data protection and is currently adapting its data protection laws for this purpose. (European Commission 2019a) . South American countries such as Brazil are also currently working on new data protection laws that will incorporate the main features of the GDPR. (Cannataci 2018) .

In parallel, some international groups that operate in the EU and therefore have to comply with the GDPR are also implementing the GDPR internationally as their data protection standard (Müller 2019).

In Germany, responsibility for data protection is divided among various bodies: The Federal Commissioner for Data Protection and Freedom of Information (BFDI) is responsible for the data security of federal public bodies, while the data protection authorities of the Länder are responsible for the respective resident public bodies/municipalities and companies. The BFDI represents Germany at the International Data Protection Conference (IDSK) and is traditionally responsible for companies in the telecommunications and postal services sectors. Data protection law is basically designed as a "prohibition law with reservation of permission". In concrete terms, this means that any processing of personal data is prohibited unless a relevant authorisation is regulated somewhere (Interview 2019).

From a supervisory perspective, the construct of the Prohibition Act with the reservation of permission is also relevant because it means that every data processor must be able to prove to the supervisory authorities that there is a legal basis for its data processing. The burden of proof therefore initially lies with the respective data processor.

If personal data is transferred across borders, e.g. to China, the GDPR generally applies in the case of Germany: Therefore, GDPR-compliant regulations must be found for this, as has been done with Japan. Data transfer to countries where the data is not handled in accordance with the GDPR standards is not permitted.

Two principles apply to international data transfers:

1. If data protection is similar in both countries, then data can be exchanged (adequacy decision at EU level). This is the case, for example, with Japan or the USA.
2. If there is no adequacy decision (e.g. with China), individual companies are responsible for complying with the GDPR. The principle of the "responsible entity" applies here. For a Chinese subsidiary in Germany, the GDPR applies to data in Germany and to data transfers to China. For German companies, the same applies. Data from German subsidiaries in China that is used in China is not subject to the GDPR (Interview, 2019).

The transfer of data with the United States of America is regulated by a ruling of the European Court of Justice. Data may be transferred because it is also considered secure in the USA according to the GDPR.

When transferring data between Germany and China, the DSGVO applies and the CSL must be observed. A joint consideration or regulation with China on data transfer and the contradictory requirements of the DSGVO and the CSL is still pending. Legal certainty for companies is lacking here. According to the BFDI, there is currently no China-specific approach, neither from the BFDI nor from the German Data Protection Conference. A dialogue is made more difficult by the fact that China is not a member of the International Data Protection Conference IDSK. One reason for this is that there is no data protection authority in China. Hong Kong, however, is a member of the IDSK (Interview 2019).

2.7.2 Sanction and control lists

Chinese actors in the innovation system are on sanctions lists that must be observed by German actors, and cooperation with China is subject to controls, e.g. in areas that may also include military aspects (dual use problem). The lists are therefore relevant to cooperation and innovation.

Sanction lists are official lists of persons, institutions or goods that are subject to a restriction by the list creator. For example, in German research institutions such as DLR, when non-EU citizens are recruited, checks are made to see whether the persons are on a list that was drawn up, for example, after the terrorist attacks of 11 September 2001. As a research institution, DLR also checks projects for compatibility with sanctions and control lists.

Such lists are relevant for the innovation system if they affect and possibly restrict technologically oriented economic or R&D cooperations. This is the case, for example, with Export control lists in Germany (Federal Office of Economics and Export Control (BAFA) 2019) or the so-called "Entity List" of the US Department of Commerce, Bureau of Industry & Security (Bureau of Industry and Security 2019a) .

The control lists for Germany primarily target goods and services, including research cooperation up to workshops and conferences, with dual use (dual-use goods), i.e. things that can be used for civilian and military purposes (EU Regulation No. 833/2014, amended by EU Regulation No. 960/2014). These items are defined in EU Regulation 2017/2268 (which amends EC Regulation No 428/2009). In the case of joint research and development projects or also projects abroad, it may be a case of "export of technology", which may fall under Art. 2 of EU Regulation No. 833/2014 and which must be examined with regard to the object of the research and also the partners. This is especially the case with countries like China, where civilian research is blurredly separated from military research. To determine the purpose of a cooperation, the information provided by the researchers in the project outline must be used on the one hand. On the other hand, the list of "dual-use goods and technologies" in the EU Delegated Regulation 2017/2268 must be examined. It is the responsibility of the individual actors to contact BAFA in possible dual use relevant scientific projects in and with China, which decides on the admissibility. BAFA has published a handout on this subject (Federal Office of Economics and Export Control (BAFA) 2016) . In 2014, the DFG and the Leopoldina published a handout on general questions regarding security-relevant research. (German Research Foundation (DFG) and Leopoldina National Academy of Sciences 2014). .

With regard to dual-use aspects, a relatively narrowly defined subject area becomes relevant for forms of innovation and cooperation with and in China in the case of German export control. The US government's regulations reach further and use the concept of "national security" as a criterion for placing facilities on a sanctions list:

"Since its initial publication, grounds for inclusion on the Entity List have expanded to activities sanctioned by the State Department and activities contrary to U.S. national security and/or foreign policy interests." (Bureau of Industry and Security 2019a)

The relevance of this "entity list" became more widely known when the US government added the

Chinese technology provider Huawei to the list in spring 2019. Subsidiaries in Europe and Germany, among others, are also affected. (Bureau of Industry and Security 2019b) .

Cooperation with Huawei is thus currently restricted, at least if a company or research institution also wants to cooperate with the USA. The current list (July 2019) also includes Chinese research institutions and universities, e.g. the National Supercomputing Center Guangzhou, an institute of the top Chinese university Sun Yat-Sen University, which may also cooperate with Germany (according to the Chinese website, with the University of Cologne or FU Berlin, among others, and with a total of 58 European partners). In the case of cooperation with the Chinese university and especially the institutes mentioned in the list, the German cooperation partner must find out beforehand what it must observe in order not to jeopardise its existing US cooperation. In practice, globally active German technology actors must regularly check whether their projects with Chinese participation are subject to a restriction and whether their Chinese cooperation partners appear on lists and what implications this would have.

2.7.3 Under-regulation as an instrument to promote innovation

The system of planning and action already described between the party and central government agencies, which set the direction, the provinces and cities, which organise the implementation of the guidelines, and the business enterprises and scientific institutions, which coordinate their activities according to the guidelines, leads to the impression of a common goal for outsiders. Interests of the state are brought into line with the interests of the economy. *"The far-reaching congruence of interests and goals of the actors in both spheres makes it possible for politics and corporate governance to mesh [...]. The boundaries between regulators and regulated are blurred"* (Taube 2018b, p. 18) . Taube (2018a) assumes that China deliberately allows underregulation for certain new products or even services in order to permit innovative competition. Taube distinguishes between three different types (Taube 2018a, p. 23) :

(1) *"The state deliberately refrains from regulating technologies and business models that are in the process of being developed, in order to allow room for experimentation and the collection of empirical values.*

(2) *Entrepreneurs try to undermine state regulations. This can be done, for example, by exploiting information asymmetries or state implementation deficits.*

(3) *Subordinate (local) government bodies deliberately override or ignore central government requirements in their jurisdictions to encourage local companies to do business. "*

Observations on "under-regulation" in China show that new technologies only receive a regulatory framework or existing regulations are adapted after about five to ten years (Taube 2018a). The central directional guidelines of the government in China give the differently developed provinces the opportunity to find specific implementation regulations in each case. According to Taube's assumption, "under-regulation" is partly deliberate, but partly also due to a time lag and complex questions of regulation. In this way, China also repeatedly tests regulations in smaller formats and observes the development in order to subsequently shape general regulation (Interview 2019). According to German business representatives, it makes sense, for example, for the development of the western provinces, to introduce regulations there (e.g. on the ratio of equity to debt capital for investments) differently or later than in the more developed eastern provinces (Interview, 2019).

The Chinese approach of consciously or unconsciously not formulating laws and regulations down to the last detail is not only related to innovation framework conditions, but it is also steeped in Chinese tradition and linked to the challenge of responding to the country's diversity with central regulations. In this respect, the Chinese approach is quite comparable with the sometimes delayed implementation of European regulations in the respective national regulations by the member states (e.g. BMWi response to the written question on non-implemented EU directives 2014 (Federal Ministry for Economic Affairs and Energy (BMWi) 2014) .

It is not possible within the scope of the study to make a comparison of regulatory times and intentions for delays due to the complexity of the different regulatory instances in Europe and China.

2.7.4 Technical norms and standards

Technical norms and standards are decisive factors in innovation activities of companies and institutions. Especially in high-tech fields such as information technology or mechanical engineering, general standards are important to create compatibility between different devices, systems and applications and thus larger markets. From this perspective, there is a general interest in developing global standards in order to minimise transaction costs and to coordinate new developments. (Fägersten and Rühlig 2019) .

It has been shown that the countries and especially the companies that initially developed the standards have been able to reap great economic benefits from their position. Companies like Microsoft, Qualcomm and Google have also been so economically successful precisely because they have been able to set global standards (Arcesati 2019) . While international standardisation has so far been mainly in the hands of the USA, Europe and Japan, China's importance has increased in recent years. The country is increasingly changing from a "standard-taker" to a "standard-maker", i.e. it is developing its own standards and is also taking on a greater role in the large multilateral institutions such as the International Telecommunication Union (ITU) and the International Organisation for Standardisation (ISO). (Arcesati 2019) .

For China, a more active role of its own in technical standardisation is of interest on the one hand because it can give Chinese companies market advantages. At the same time, it is also a way to reduce the increased expenditure on licence fees that Chinese companies have been paying for the use of foreign technologies in recent years. (Arcesati 2019) . For China, it is another step towards autonomy from foreign companies and cost reduction.

In addition to the path through the international institutions of standardisation, a bilateral approach to the dissemination of its own standards can also be seen on the Chinese side. For example, the Belt and Road Initiative, and in particular the so-called "Digital Silk Road", is used as a vehicle to enforce Chinese standards in the target countries. (Shi-Kupfer and Ohlberg 2019) . Since the projects are financed by the Chinese side and for the most part also implemented by Chinese companies, their own standards are applied. The focus is on areas such as infrastructure and mobility, but also on information technology, artificial intelligence and autonomous driving. If Chinese technical standards prevail locally, for example in African countries or in Central Asia, it will become more difficult for companies from third countries to compete in the corresponding markets. (Fägersten and Rühlig 2019) . It is in Europe's interest to seek cooperation with China on standardisation issues:

"First, Europe should reach out to China to highlight the obvious benefits of remaining in the existing institutional framework. If the Chinese party-state encourages China's companies to comply with global standards it will increase its global competitiveness and the quality of its exported products. In the long run, this policy will be much more profitable for China than its current course of promoting Chinese standards in BRI countries that provide a competitive advantage for Chinese companies in the short term. In sum, the EU should aim to make a case against short-term protectionism for the sake of long-term competitiveness. " (Fägersten and Rühlig 2019, p. 17)

China's rise in the field of technical standards and norms not only results in greater competition and possibly a loss of technology use fees for German companies, but also in higher transaction costs due to various standards and technical requirements that have to be met. The possibilities for foreign companies to influence the development of standards in China are rather small, as the state in the form of the Standardisation Administration of China (SAC) keeps control in its own hands. This is a major difference to the European procedure, in which foreign companies, such as the Chinese companies ZTE and Huawei in the case of telecommunications technology, are also involved. (Arcesati 2019) .

2.8 Conclusion on the role of state guidance

In China, the Communist Party has the central planning and decision-making role. The Party determines the government and it is represented at all levels in parallel with governmental and administrative structures. These hierarchical structures of the party and the governmental structure associated with it provide centralised decision-making mechanisms to rapidly develop innovation policy instruments and regulations.

A characteristic of Chinese policy is the conception of long-term plans with ambitious goals, both of a fundamental nature and with a thematic focus. These plans sometimes state concrete goals, but are rather understood as visions and adaptable orientations. They serve as a common thread for action at the various decision-making levels.

The European Union as a whole has an economic and innovation policy strength comparable to China. However, the European association of individual, independent, democratically governed countries has fundamentally different decision-making channels and forms of implementation. However, the importance of ambitious long-term goals also makes sense in Europe. A clearer positioning in Europe is demanded by various actors, also as a reaction to Chinese plans for the next technological leap (e.g. MIC 2025) and for stronger international market development (e.g. BRI). The EU Commission and the member states should work on a European target definition and then also implement it together.

In the European view, China is often seen as a central state-led bloc. China's strategic actions do follow a centrally guided social and economic planning policy. However, these are to a large extent translated into concrete implementation regulations and measures in the provinces and cities. In all the central Chinese initiatives considered, instruments and measures of many actors, central and local, private and public, are visible. The motives for participating in central initiatives with their own measures are manifold. The fulfilment of the expectations of the communist party, which is represented everywhere, is an important reason. It is not proven and comprehensible how useful all measures are and there is a lack of evidence on the efficiency of implementation. However, the result of this broad engagement is impressive overarching momentum with visible results and large budgets. A similar, more mission-oriented joint approach of the member states in Europe, in addition to the above-mentioned common objective, seems to make sense.

The diversity and also disparity between the provinces and cities in China is not very present in the discussion. Yet the regulatory and financial power of the provinces creates opportunities for international partners. In addition to the broad discussion of the central Chinese plans, it would make sense to focus more on the strengths and opportunities of cooperation with the provinces. This would require a better analysis and understanding of the provinces and their framework conditions and actors.

In the area of technology development, vertical industrial and innovation policy plays the essential role in China. This means that the government centrally and at the provincial level promotes individual technologies, industries and actors in a special way and also protects them externally. This also applies to the science sector, where individual universities receive special support. The approach based on vertical themes and individual actors is also reflected in the budgets and tasks of the research institutions, e.g. in the so-called megaprojects. On the one hand, this selective industrial policy has successfully led to the emergence of some leading technologies and is to be continued. On the other hand, the effectiveness of the development financed with large sums of money is unclear. In other non-highlighted technology areas, technological performance has not been able to develop in an internationally comparable manner.

China recognises the limits of its previous policies and is analysing the path it has taken so far. A recent study by the World Bank with the China Development Council states that China needs new growth drivers for further development and to maintain domestic stability, and that this also requires a redistribution of resources. The newer planning approaches already envisage broader technology

development. The approach of stronger indigenous innovation development, as formulated in MIC 2025, is also not necessarily contrary to international cooperation and openness to international partners in China. The recommendations from the World Bank/DRC study are similar to demands made by Western actors on China and provide a basis for dialogue.

A state-led selective industrial policy cannot be transferred to Germany. In Germany, innovation promotion pursues a horizontal, open-topic support approach, the focus of which is steered by the innovation needs of the market. Nevertheless, the fundamental medium- and long-term definition of concrete innovation policy goals in individual key sectors appears to make sense as a supplement. The orientation power of these plans for the Chinese provinces and also for research and business is great, even if the share of orientation enforced by the authoritarian form of society remains unclear. A basic orientation guide would also be helpful for Germany or, as mentioned above, the EU.

In contrast to Europe, China has managed to increase R&D spending so much that even with a massive increase in GDP, the R&D rate has continued to rise, overtaking the EU in absolute terms. At the same time, the provinces in China have a very different share in these figures, in a similar way as the states of the EU have in the EU result. China and the EU are faced with the challenge of equalising innovation opportunities in all provinces and member states and must develop appropriate instruments to support this.

China's research system and project funding has been reformed and, according to the first visible results, improved. It is more transparent, more clearly coordinated and structured. Project funding by the Ministry of Research MOST is similar in size to that of the BMBF. However, the MOST funds fewer projects, these are larger and it focuses with almost half of the budget on the few large programmes of "megaprojects" that are funded with various instruments. The MOST also provides funding based on results and budget and thus finances successful research retrospectively, which is not yet possible with the BMBF. Although the data basis for a system comparison of research funding in China and Germany is insufficient, the consideration of the reform approach in China provides the impetus for an analysis of the German research funding system.

Innovative public procurement is used in China as a demand-side instrument to support technology development and is effective in technology development and the creation of new markets. In Germany, this instrument is also assessed positively and, due to the rather restrained use to date, a high, still open potential is seen.

It is important that the transfer of data between Germany and China is largely unrestricted, secure and legally compliant. The European Directive on the Protection of Personal Data (DSGVO) (no access for secret services, among other things) and the Chinese Cyber Security Law are mutually exclusive. Currently, no personal data may be transferred from Europe to China. Further innovative development in the area of personal data processing requires coordination with China. A handout or advice on this topic for German actors and Chinese companies (located in Germany) would seem to make sense.

Sanction lists and their implications are a noteworthy and, in the negative case, limiting factor for Germany's international innovation development, which is geared towards open exchange. In cases of attention and also non-observance, long-standing strands of cooperation can be jeopardised. Since few actors, e.g. at universities, regularly deal with these issues, the establishment of a support process for innovation actors should be examined - BAFA already does this for its competences - or existing offers should be expanded and, for example, the implications of the US lists should also be included.

There are several reasons for the perceived "under-regulation" of many new product and service offerings in China. Among other things, regulations need to be balanced so that they are just as applicable to the well-developed regions in eastern China as to the regions in western China. At the same time, regulation or under-regulation can provide a competitive advantage for the Chinese economy, or for the individual provinces in competition with each other. European countries are also

delaying the introduction of EU regulations for various reasons.

China is striving both to set its own standards more strongly and to represent its interests through greater engagement and influence in multilateral standardisation bodies. As the field of technical norms and standards is of great importance for economic development and innovation, Germany and the EU should actively pay attention to China's engagement. China must be integrated into multilateral institutions to prevent the establishment of parallel institutions or an increasingly Chinese focus on bilateral cooperation. At the same time, care should also be taken to ensure that its own interests are adequately represented, e.g. through its own competent representation in the decisive bodies. It should be observed that China adheres to international rules and that there is a fair balance of interests. Suitable monitoring of the German presence in committees would be helpful in this regard. For the Chinese side, too, the long-term gains from comprehensive international cooperation take precedence over the short-term gains from bilateral cooperation.

3. Actors in the research and innovation system

Qualification and competence of the labour force is one of the crucial aspects for a country's innovation capacity and success. Consequently, skilled workers play a key role in the innovation competition (Leszczensky et al. 2008) . The Chinese government recognised the importance of "talent" at the turn of the millennium and placed students and scientists at the centre of efforts at the central and provincial levels to develop the country into a more self-reliant, knowledge-based economy. (Bekkers et al. 2019; Cao et al. 2019) . The envisaged next leap in innovation requires specific well-trained personnel and a high number of scientifically minded and innovative people. (ChinaPower Project 2019) .

From the beginning, China has focused on developing its own domestic capacity, e.g. by building universities of excellence (e.g. the 211 and 985 programmes, which were merged in 2017 to form the "Double First-Class University Programmes"). The "Double First Class University Programme" is intended to produce excellent universities, although an exact number has not been specified (State Council of the People's Republic of China 2015a) . Today, the Times Higher Education Ranking 2019 finds three Chinese universities among the TOP 100 and nine universities among the TOP 200 (Germany is at eight and 23). (Times Higher Education 2019) .

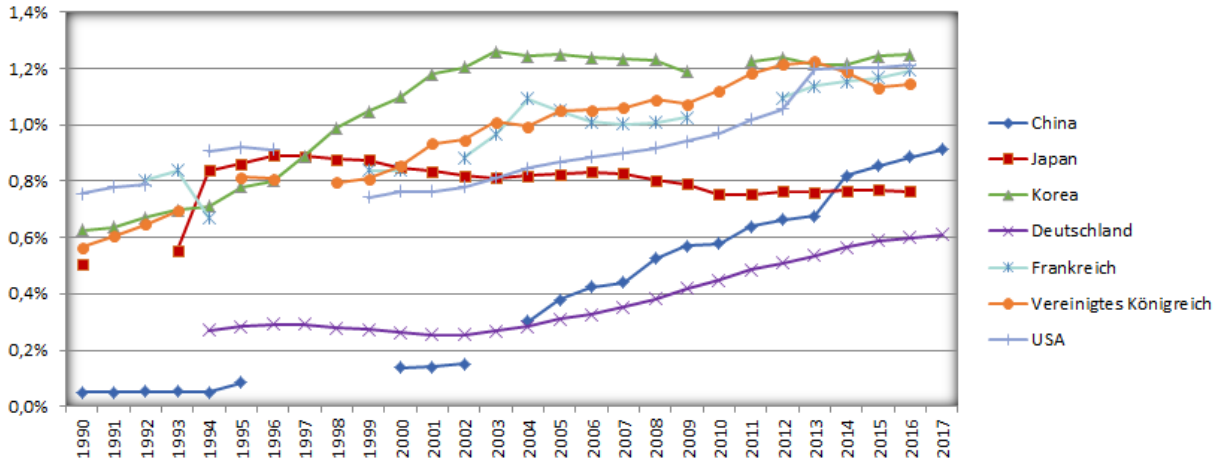
On the other hand, the training of Chinese talents abroad and the return of these people were the second pillar to quickly build up expertise. In addition to these two components, the targeted return of Chinese from abroad and the recruitment of international students and experts to China have played an increasingly important role for about 10 years.

3.1 China's academisation

In other industrialised countries (here: South Korea, France, USA, United Kingdom), the proportion of university graduates per year is around 1.2% of the total population (see Figure 17). It can be seen that China has been on a rapid path towards "academisation" since the turn of the millennium and is now at a share of about 1%. The generations since the beginning of this millennium have increasingly had an academic education.

The comparatively low German figures are presumably shaped by the dual training system: corresponding degrees are achieved academically in most other countries and therefore represent a *"special feature of the German education system*" (Gehrke et al. 2019, p. 14) . Since 2019, China has issued a plan for the development and expansion of vocational education and training. (State Council of the People's Republic of China 2019) .

Figure 17: Share of graduates per year in the total population (1990-2017)[1)]



1) Figures in %.
Source: Own representation based on data from Frietsch et al. 2018a

The rapid growth in academisation as China's higher education system develops and expands means that twice as many students graduated in 2017 alone than in the US. A significant increase already from 2013 to 2014 was made possible by an announcement by the MoE to admit more master's students and doctoral candidates. (Ministry of Education (中华人民共和国教育部）; National Development and Reform Commission (国家发展改革委员会) 2012). . This consequently meant the largest ever influx of graduates into the labour market. (Stapleton 2017) . According to UNESCO figures, the proportion of students in a cohort increased from 20% in 2009 to 50% in 2018. (UNESCO 2019b) .

While the unemployment rate of graduates remains relatively low and stable according to official statistics, studies describe that while most graduates find employment, a large number of them work only in part-time or low-paid jobs. (Stapleton 2017) .

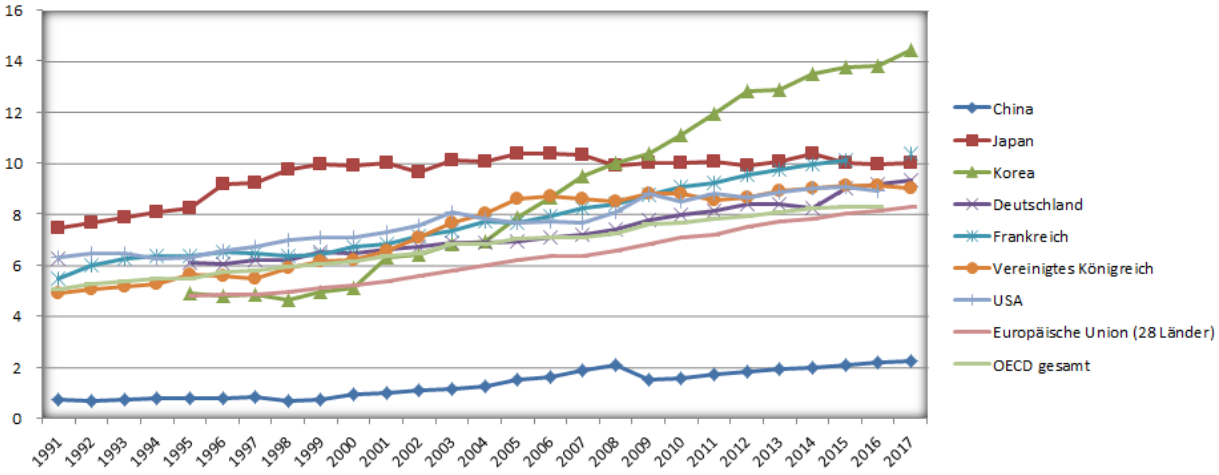
This is a major and growing problem in the context of Chinese society, where "advancement through education" is a very essential feature of recognition (Minzner 2018) . Engineers, economists and scientists seem to be excluded from this problem so far. In addition to the subject area, however, there also seem to be deficits in the skills of university graduates that make it difficult for them to enter the labour market, because graduates often do not have the necessary skills that Chinese companies demand for corresponding positions. (Stapleton 2017) . According to Molnar et. al. (2015), these factors indicate, among other things, that institutions of higher education lag behind the needs of the market and provide qualifications that the market does not require. (Molnar et al. 2015) .

A low quality of university education seems to be the case across the board. However, German interviewees in China speak of a significant increase in the qualifications of Chinese interns and students in recent years. However, mainly internationally open, English-speaking people apply to German companies (Interview 2019), who were educated at Chinese universities, especially in Beijing and Shanghai, which are among the top universities.

The rapid increase in academisation in China since 2000 and the still comparatively low overall academisation of the Chinese population indicate that there are relatively few people with a university education in the group of people over 40 in China today. Accordingly, there are only a few academics with many years of professional experience at universities and companies. While the proportion of university graduates in the UK, for example, doubled from a high level within 30 years, the proportion in China has increased fivefold in the last 17 years. The large number of well-educated, young academics entering the labour market and the research institutes is not matched by a corresponding number of well-educated, experienced managers. This lack of leadership and decision-making competence based on

professional and life experience can possibly inhibit the necessary innovation development across the board.

Figure 18: Scientists per 1000 employees (1991-2017)



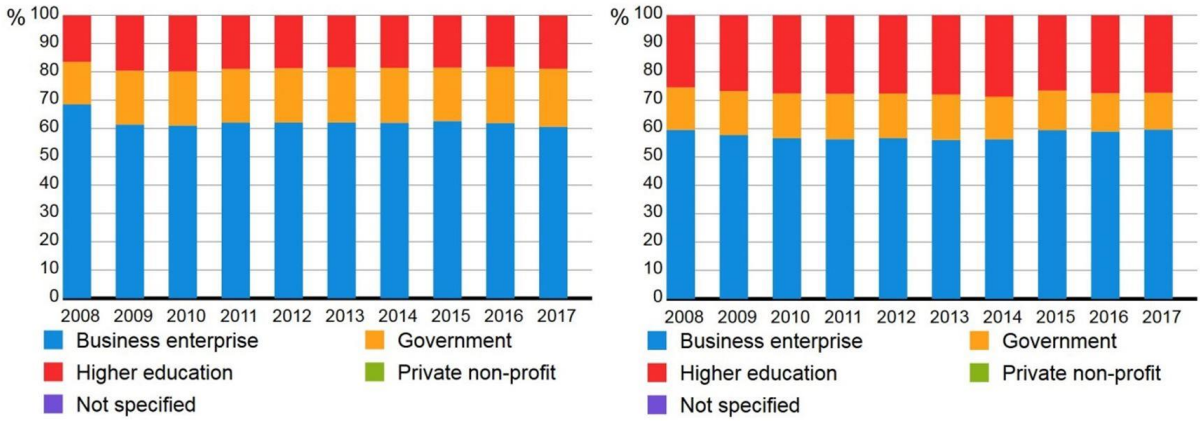
Source: Own representation based on (OECD 2019b)

An innovation-driven economy needs people who think and act scientifically. In addition to the fundamental academisation of a society through the proof of a tertiary education (university degree), the representation of the proportion of scientifically employed personnel makes a further statement about the capacity for innovation. A ratio of about 10 scientists per 1,000 employees for knowledge-driven economies seems to represent a good ratio (South Korea is an exception not discussed here), on which a kind of development plateau of many of the countries considered also emerges (see Figure 18). The rapid increase in university graduates in China in recent years has not been accompanied to the same extent by an increase in scientific activity. According to figures from UNESCO, the number of people employed in science in 2018 is 1,740,442 full-time-equivalent (UNESCO 2019b) . The proportion of scientists in Germany or the European Union has grown more than in China over the past 10 years.

While the number of Chinese university graduates has increased fivefold in the last 17 years, as shown above, the number of scientists per 1,000 employees has only roughly doubled.

One reason for this development is that there are few jobs for scientists and the working conditions for young university graduates are relatively unattractive (Interview 2019). The Chinese government has recognised this: in March 2018, the new MOST Minister Wang pointed out in his inaugural speech that the science sector is not attractive enough for young scientists due to structural problems. (Frietsch et al. 2018a, p. 55). .

Figure 19: Proportion of scientists in sectors of different activities (2008-2017) (left: China, right: Germany)



Source: UNESCO 2019b , image retrieved on 24 Oct 2019

The distribution of scientists across different sectors of activity is comparatively similar in China and Germany. When considering the private sector, public research institutions and universities, a share of 60 % of employees work in the private sector. China has a slightly higher share of employees in universities, Germany has a higher share in research institutions. Overall, the distribution seems to be stable over the years. The boom of the Chinese private sector in the IT sector with large tech companies and the research capacities built up there rapidly in the last 10 years and the staff hired are not noticeable in the figures The rapid build-up of university capacities is also not reflected in the general distribution: the number of university research and development centres was 5,159 in 2006 and rose to 13,062 by 2016 (Frietsch et al. 2018a, p. 59). This could be explained by the fact that the development of employment numbers in all three sectors has followed a similar pattern over the years.

The reform of higher education in China (university enrolment expansion) since 1999 has improved the educational attainment of young Chinese, but it has also led to a deterioration in the quality of education and a lack of infrastructure at universities. It also affects the absorptive capacity of the labour market for academics.

3.2 Talent mobility

According to Jing (2019b), in contrast to past years, China today offers Chinese talents a variety of good training opportunities in China. So, it is no longer important to go abroad for a good education. Nevertheless, talent mobility remains an essential source of know-how gain in China. This means education and training abroad (especially in the US, Canada, Australia and the EU) and the return of Chinese talent to their home country, and increasingly also the immigration of foreign scientists and students to China.

3.2.1 Mobility of Chinese students

In general, the number of mobile Chinese students and academics has increased rapidly in the first two decades of the 21st century. While in 2000 just under 39,000 Chinese went abroad and of these just under a quarter (just over 9,000, i.e. 23.4%) returned, in 2017 alone over 608,000 Chinese left China and 480,000 returned. (Cao et al. 2019) . This represents a fifteen-fold increase.

Students of Chinese origin represent the largest group of internationally mobile students worldwide. (o.A. 2018) In 2016, around 865,000 students from China were enrolled at universities abroad (see Figure 20). (Heublein et al. 2019) (see Figure 20).

Figure 20: International student mobility from the main countries of origin (2008-2016)

Herkunftsländer	Jahr	Anzahl der Studierenden im Ausland
China[1]	2008	473.742
	2012	705.057
	2016	865.337
Indien[2]	2008	186.033
	2012	191.779
	2016	301.406
Deutschland[3]	2008	105.600
	2012	139.200
	2016	144.900
Südkorea[2]	2008	117.533
	2012	121.198
	2016	104.992
Nigeria[2]	2008	41.299
	2012	57.298
	2016	95.731
Frankreich[2]	2008	46.978
	2012	64.196
	2016	90.543

Source: Heublein et al. 2019 , S. 18

Highly developed industrialised countries are the preferred destinations for Chinese students. For example, the numbers of Chinese students in the United States [1], the United Kingdom and Japan have [2]increased significantly in recent years: since 2009, China has been the most common country of origin for foreign students in the US (Ministry of Science and Technology (MOST) 2018) .

Of the approximately 865,000 Chinese students abroad in 2016, about 330,000 had American universities as their destination. About 32% of foreign students in the US that year were Chinese. It is noted that Chinese students, the majority as "freemovers", are a major economic driver for American universities (as they are in the UK and other countries with tuition fees). According to the BBC, the contribution of Chinese students and their families in the US in 2017-2018 was about $13 billion (about RMB 81 billion), which includes both tuition fees and living expenses (BBC News 2019; ChinaPower Project 2019) .

What is remarkable in this context is the change in the international perception of Chinese mobility in a short period of time - especially in the USA, presumably as a result of the policies of the current US administration. In 2017, Veugelers wrote. (Veugelers 2017) that Chinese mobility to the US is to the benefit of both countries. While China benefits from catch-up development, the US is able to maintain its scientific leadership in the world with the help of Chinese scientists. In 2019, however, US leaders are calling Chinese mobility a risk of a technology drain from the US, and Chinese are reportedly feeling increasingly unwelcome in the US. While visa issuance is becoming more difficult for Chinese, access to research funding and career opportunities in the US are also increasingly limited for Chinese (referred to as the "bamboo ceiling") (Jing 2019a) .

In total, over 5.2 million Chinese had been educated abroad by 2017. 3.1 million of them subsequently moved back to China, which represents a return rate of 60.3%. It is interesting to note that of the 1.9 million non-returners, about 1.45 million were still students in current study abroad. Thus, the return rate is as high as 83.7% of those who had already completed their studies. (Cao et al. 2019; Dong 2019).

[1] "The USA is by far the most important host country for international students, with around 971,000 students from abroad. It is followed by the UK (432,000), Australia (336,000), Germany (252,000) and France (245,000)" (Heublein et al. 2019.
[2] Heublein et. al. lists Australia ahead of Japan as the most important destination countries for Chinese students after the USA and Great Britain (p. 20).

Table 4: Mobility figures of Chinese students (outgoing and returning)

Year	Number of students, who go abroad	Number of returning students	Cumulative number of students who have been abroad	Cumulative number of returned students
2000	38.989	9.121	340.000	**130.000**
2005	118.515	34.987	933.400	**232.900**
2010	284.700	134.800	1.905.400	**632.200**
2017	**608.300**	**480.900**	**5.194.900**	**3.132.000**

Source: own representation based on Cao et al. 2019

The China Scholarship Council (CSC), an agency of the Chinese Ministry of Education, and its scholarship programmes are the largest funder of Chinese doctoral students and scholars going abroad, as well as foreigners coming to China. Scholarships are open to undergraduates, master's and doctoral students, and scholars (both juniors and seniors).

3.2.2 China as a destination country for foreign students

The recruitment of international students and scholars is becoming increasingly important for China. Building a knowledge-based economy and society is increasingly dependent on the availability of talent.[3] This has also led to an increased focus in China on policies that recruit international students and increase the number of those who stay in China for the long term. This is true at the national level as well as for provinces, cities and universities. (Gao and Wit 2017).

The overall attractiveness of China as a destination country for mobile people has increased. China now ranks twentieth in the world as an attractive destination for migrant workers, according to Jing (2019b) (Jing 2019b) . However, Chinese returnees probably account for a significant share of these figures.

China has also become a destination country for students, especially from Asia and Africa. In 2018, a total of about 492,185 international students from 196 countries were enrolled in 1004 Chinese higher education institutions (Ministry of Education 2019) . The People's Republic has thus almost achieved its goal of increasing the number of foreign students in China to 500,000. (Gao and Wit 2017; Heublein et al. 2019) [4]. Heublein gives a very different figure for China of around 142,000 incoming students in 2016, 8145 of whom were enrolled Germans. (Heublein et al. 2019) .

China is an attractive place to study, especially for students from South Korea, Thailand and Pakistan. (Ministry of Education 2019) . The BRI plays an increasingly important role in this context. In 2017, students from BRI countries accounted for nearly 64.9 per cent of foreign students in China (o.A. 2018) . About 63,000 of the international students were supported by Chinese Government Scholarships (CSC) in 2018 . (Ministry of Education 2019) . In addition to these, there are special BRI scholarship programmes According to the China Daily news channel, at least 160 study programmes in China will be supported for students from BRI countries by 2020 . (China Daily 2017) . In addition, there are many provincial, city and university scholarship programmes.

African students make up an ever-increasing proportion of foreign students in China. There are now about 80,000 Africans studying in China, of which about 50,000 are on full scholarships from the

[3] For a discussion of state policy strategies in the recruitment of international students see for example "Policy mobilities in the race for talent: competitive state strategies in international student mobility", Geddie 2015.

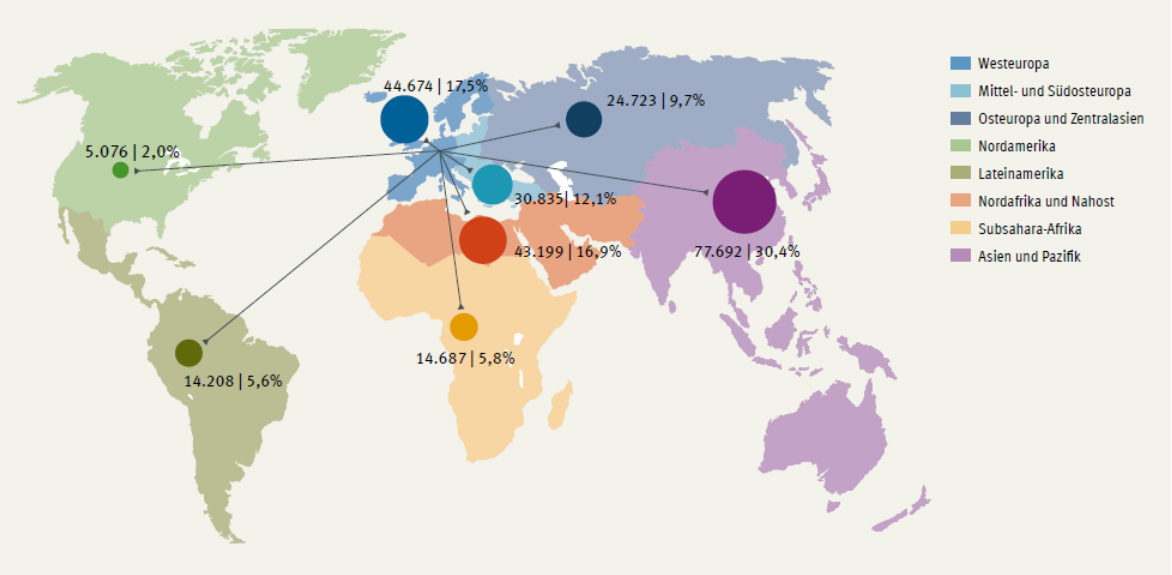
[4] Heublein et al. 2019 notes, however, with regard to the officially available numbers of international students in China: "In the case of China, a clear discrepancy becomes apparent between the number of international students in tertiary education issued by UNESCO and the number reported by China in the context of target achievement. This is due to a broader definition [on the Chinese side] of international students that includes, for example, language students" (p. 27).

Chinese government. (Erling 2018) . In 2012, only about 27,000 Africans were studying in China. (Müchler and Sun 2014) . Thus, the number of African students in China has roughly tripled in six years. In 2016, China already received significantly more students from the African continent than the USA and the UK (about 40,000 each) and was the second most popular destination for African students behind France (over 95,000). (ChinaPower Project 2017) . In comparison, about 26,000 African students are enrolled in Germany. (Ebert et al. 2018; Apolinarski and Brandt 2018) .

3.2.3 Student mobility to and from Germany

As in China, foreign students from the Asia-Pacific region represent a large proportion in Germany, with 77,000 in 2018 (see Figure 21). (Heublein et al. 2019) (see Figure 21). In Germany, 47% of foreign students at universities are from Europe, 33% from Asia, 11% from the Americas, 9% from Africa (Deutsches Studentenwerk e.V. 2019) . Chinese students in 2017 (35,000) make up the largest proportion of all foreign students, at 13.2%. (Frietsch et al. 2018a) . The importance of Chinese students in Germany is not nearly as great as in the USA. Neither are Chinese students a strong economic factor, nor are German universities as dependent on a country as the USA in their search for excellent academics.

Figure 21: Foreign students in Germany with the intention to graduate by region of origin in 2018



Source: Heublein et al. 2019

In 2016, the most important destination countries for German students were Austria, the Netherlands, the United Kingdom and Switzerland; 74% of all German students abroad chose a Western European country as their host country. In 2016, 8,145 students went to China (see Figure 22). This means that about 1.6% of all foreign students in China are German. In comparison, about 1% of all foreign students in the USA are German. China is the most important non-European destination after the USA. A total of about 144,900 German students were enrolled abroad in 2016 (Heublein et al. 2019) .

Figure 22: German students abroad by major host countries 2015 and 20161)

Gastland	2015		2016	
	Anzahl	in %	Anzahl	in %
Österreich	27.563	19,7	28.220	19,5
Niederlande	21.530	15,4	21.956	15,2
Großbritannien	15.410	11,0	15.770	10,9
Schweiz	14.647	10,5	14.609	10,1
USA	10.145	7,3	10.169	7,0
China	7.536	5,4	8.145	5,6
Frankreich	6.406	4,6	6.007	4,1
Schweden[3]	4.620	3,3	4.620	3,2
Dänemark[3]	3.554	2,5	3.554	2,5
Türkei[4]	706	0,5	3.363	2,3
Ungarn	3.106	2,2	3.232	2,2
Spanien	2.497	1,8	2.756	1,9
Kanada[3]	1.827	1,3	1.827	1,3
Griechenland[3]	1.637	1,2	1.637	1,1
Portugal	1.422	1,0	1.622	1,1
Italien[3]	1.412	1,0	1.412	1,0
Norwegen[3]	1.306	0,9	1.306	0,9
Polen	1.090	0,8	1.239	0,9
Australien	1.147	0,8	1.202	0,8
Rumänien	898	0,6	1.187	0,8

1) Taiwan, Hong Kong and Macao are considered separately here. The countries are not included in Mainland China. Taiwan is also increasingly attracting foreign students, but continues to play a much smaller role for the EU than Mainland China. (Heublein et al. 2019) .
Source: Heublein et al. 2019 , p. 87

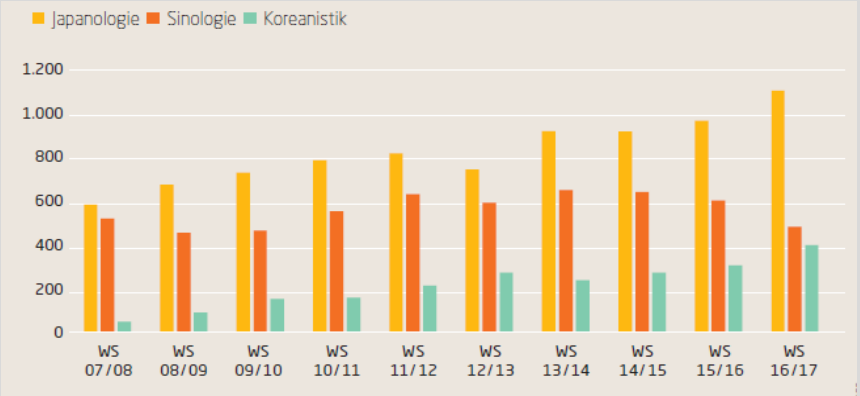
Textbox 5: Excursus Chinese Language and Cultural Competence in Germany

Funded by the BMBF, MERICS conducted a needs analysis of the competence on Modern China in Germany at the end of 2017. (Stepan et al. 2018) . Dealing with the growing importance of China as a global and self-confident innovation actor requires "*differentiated knowledge about a country whose image in Germany today is often still shaped by outdated ideas and clichés*". (Stepan et al. 2018, p. 8) . Such knowledge is important in order to differentiate where there is room for cooperation with China and where critical confrontations regarding diplomacy, political decision-making processes and jurisprudence are necessary. In the study, MERICS gives an overview of the development of China competence in Germany and provides numerous recommendations on how it can be expanded:

- In order to impart China competence already in schools, China scholars should be regularly consulted by ministries and school authorities and give lectures at schools and vocational schools. Further training for teachers and project weeks can also increase knowledge of China. Up to now, China has been a marginal topic at German schools and hardly appears even in subjects such as history, geography or economics.
- In addition, Chinese lessons should be established in all federal states as a fixed component of the languages offered. A fully integrated Chinese language course in schools strengthens Chinese competence and does not impose any additional burdens on the students. MERICS found that in France, for example, about seven times as many students (about 38,000) already learn Chinese at school than in Germany.
- The development of China competence should also continue to be promoted at universities. This includes, for example, the establishment and financial support of double degree programmes at German and Chinese universities. Within this framework, German students could also be offered more opportunities to spend time in China. In addition, sinology study programmes and language courses at universities should continue to be promoted. The number of sinology students in Germany, as an approximation of the naturally larger number of Chinese language learners, is stagnating at a low level (see Figure 23). Although English is the global language of communication, specific language skills are important for in-depth

cooperation, e.g. the work of German post-docs at Chinese universities or cooperation with Chinese SMEs.

Figure 23: Development of first-year students in Sinology, Korean Studies and Japanese Studies in comparison (2007-2017)



Source: Stepan et al. 2018 , S. 56

"European institutions often lack strategic vision, in addition to language skills and knowledge of the cultural context. This gives them a decisive advantage over China." (d'Hooghe et al. 2018, p. 4)

"European governments need to invest in high-calibre, independent China expertise. Raising awareness about and responding to China's political influencing efforts in Europe can only succeed if there is sufficient impartial expertise on China in think tanks, universities, NGOs, and media across Europe. This will also help to keep out 'unwanted' Chinese money in those institutions." (Benner et al. 2018, p. 7)

3.2.4 Researcher mobility to and from China

Not only students, but also Chinese academics and researchers are drawn to foreign countries or remain there after their studies. Preferred destinations are the United States, followed by Japan, the United Kingdom and Canada; Germany is the sixth most popular destination, accounting for 4.2 per cent of mobile Chinese academics. (Frietsch et al. 2018a) . Chinese make up a large proportion of doctoral and post-doctoral students in the USA, for example: in 2015, over a fifth (22%) of the 464,000 foreign post-docs were of Chinese origin. (Cao et al. 2019) . The majority of doctoral students do their doctorates in STEM subjects (Science, Technology, Engineering and Mathematics) (see Table 5).

Table 5: Number of doctoral degrees awarded by American universities to Chinese citizens, 2006-2016

Year	PhD students	STEM PhD students
2006	4.448	4.123
2010	3.744	3.457
2015	5.374	4.970

Source: Own representation according to Cao et al. 2019, p. 9

Fewer doctoral graduates of Chinese origin return home from the USA than from the European Union (Cao et al. 2019) .

In Germany, the proportion of foreign researchers who successfully completed their doctorates was 17% of all those who successfully completed their doctorates in the 2017 examination year. Among this group, the largest proportion is of Chinese origin (16% of all foreign doctoral graduates). (Heublein et

al. 2019) .

To attract this talent to Germany and *"to share in China's innovative power and make use of its bright minds, German companies would need to make Chinese employees and research centres an integral part of their global development strategy"* (Bartsch 2016, p. 9) .

While the US is still the most popular destination for Chinese researchers and students, a new trend in subsequent employment has been emerging for several years: While in the past many top Chinese talents were recruited mainly after a US degree by large multinational companies or even universities and research institutes in the US, the situation has changed significantly in recent years. Chinese US university graduates are increasingly joining Chinese technology companies rather than large multinationals, as they expect better career opportunities there, also because these companies are now developing high technology. (Jing 2019b) . In America, this has been compounded in recent years by an increasingly anti-China stance by the US government and a sense of exclusion. The renowned MIT professor Huang Yasheng describes how it has become almost impossible for American scientists with Chinese roots to use resources from both countries for research. (Jing 2019a) . He fears that Chinese are often perceived in the USA as engineers rather than leaders. (Jing 2019b) . [5]

Even though China is not yet a target country comparable to other European countries for German researchers (see Chapter 3.2.3), China is increasingly perceived as an attractive research location despite some hurdles, as the interviews and the EURAXESS Focus Group discussion show (Interview 2019, Textbox 6).

Textbox 6: EURAXESS Focus Group Discussion

In July 2019, a so-called "EURAXESS Focus Group" discussion took place in Beijing with 9 academics from Europe (including German researchers) on the topic of "Researcher Mobility to China". All participants are currently working as PhD students or professors at renowned universities or research institutions in China. The main statements of the researchers can be summarised in the following three categories:

Motives for going to China:

- China as a research subject, e.g. China's public policy.
- In Europe or the USA, scientists would have found academic jobs less easily.
- Extensive research funding and good salaries, some of which are far above the level in Europe: "*The salaries are very good and there is funding at all compared to some countries in Europe, even if it is not easy in China to hire staff with funding*". Europeans get even better conditions than returning Chinese. The scientists have acquaintances who are actually funded through the "*1000 Talents Programme". One reason for the good financial conditions is that "China is pushing the internationalisation of universities, so there are more financial opportunities than is widely known*". However, students and researchers in Europe often lack information about this.
- Easy access to scholarships: Even foreign students who are not very well qualified can easily get a scholarship in China, although doctoral students in China with a scholarship from the Chinese Scholarship Council (CSC) are not as well paid as in Europe.
- Laboratories and other research infrastructures are additional pull factors: "*The Chinese will build whatever you need*".
- Scale: in China, academics often have the chance to work on a large scale: "*You're not just*

[5] Huang Yasheng says: "It has become almost impossible for US scientists with Chinese background to leverage the resources from both countries to do research. They have to choose sides now" (Jing 2019a); "many Chinese today perceive a 'bamboo ceiling' in the US, where they are more often seen as engineers rather than executives" (Jing 2019b).

involved in some urban planning, you can plan a whole province!"

- Growing competencies: Increasingly, researchers are coming to China not only because of the funding opportunities: "*The Chinese are really good in some areas*". That was not the case in the past. "*Soon they will come to China for excellence.*"

Perceived disadvantages and hurdles that make life in China difficult:

- Quality of life (common examples are poor air quality and the housing situation)
- Cultural differences: Difficulties in coping with the culture, such as the complicated human relationships that are often opaque to non-Chinese. Chinese also often do not know how to deal with foreigners.
- Institutional obstacles: For example, non-transparent university policies and often chaotic and inefficient management at universities and institutes make research difficult.
- Limited access to the internet: Internet access is often limited in China and the internet is often slow due to the "fire wall". There is no or difficult access to Google Scholar and other journals.
- Visa issue
- Low level of internationalisation: for example, applications for funding have to be made in Chinese. The bureaucracy in China cannot be managed without knowledge of Chinese.

China as an important career step:

- The students and researchers from Europe or the USA are mostly only in China for a short stay, as it is only seen as "*a career step*", not as "*the place to be*".

The researchers recommend going to China only at post-doc level. The basic training is much better in Europe and post-docs can make better use of the research infrastructures in China. But China should definitely be part of the life plan of European researchers.

3.2.5 China's return and recruitment programmes

To encourage and incentivise the return of Chinese and the recruitment of international scholars, China has introduced an elaborate set of measures (Publications Office of the European Union 2019) . The People's Republic wants to take greater advantage of the scientific and technical capital of mobile talents, whose mobility provides additional skills and stronger integration into international networks. (Cao et al. 2019) . The important role that returnees play in the Chinese system is reflected in the fact that, according to Cao et. al. (2019), many leadership positions are filled by returnees.

Data for students and academics indicate an increasing number of returnees. According to figures from the Chinese Ministry of Education, the number of returning Chinese students rose to 519,400 in 2018, an increase of 8% compared to the previous year 2017. (Dong 2019) . The deficit between Chinese students studying abroad and returning students to China has subsequently narrowed (Ministry of Science and Technology (MOST) 2017) . The length of stay of Chinese post-docs from science and engineering in the US has also declined slightly in recent years, with 90% of 2005 science and engineering PhDs staying for ten years; for the 2015 cohort, the proportion of those who stayed for five to ten years had declined to 70% (Cao et al. 2019) .

In addition to encouraging Chinese to return more quickly, more foreign experts are to be recruited at the same time. As part of the reform of the research system, the State Administration of Foreign Experts Office SAFEA and the National Natural Science Foundation of China NSFC were assigned to the Ministry of Research MOST in March 2018. The position of the ministry has been greatly upgraded as

a result. (Frietsch et al. 2018a, p. 55) .

Measures used to attract high-level Chinese and foreign talent include: promoting the establishment of joint laboratories, recruiting foreign experts, Sino-foreign education cooperation programmes, supporting state-funded study abroad, recommending high-level talent to international organisations, attracting Chinese studying abroad to China, and encouraging business creation and innovation.

Table 6: Compilation of essential central Chinese talent retrieval and acquisition programmes1)

Programme	Agency in charge	Target of the programme	Year initiated	Total affected number
Hundred Talent Program	CAS	scientists under 45 years old (i)	1994	**n.a.**
National Science Fund for Distinguished Young Scholars	NSFC	academic leaders under 45 old; frontier sciences and technology (d)	1994	**3454**
Chunhui Programme	MOE	Chinese expatriates for short-term services (i)	1996	**n.a.**
Cheung Kong / Changjiang Scholar Program	MOE	Endowed professorships for under 45 years old; extended to 55 years old in social sciences and humanities (i)	1998	**2948**
111 Programme	MOE & SAFEA	1,000 foreign scholars from the top 100 universities and research institutions (i)	2005	**n.a.**
Thousand Talent Program	CLGCTW	1,000 academics, corporate executives, and entrepreneurs under 55 years old to return from overseas	2008	**n.a.**
Young Thousand Talent Programme	CLGCTW	academics under 40 years old with three+ years of post-doctoral research (i)	2010	**3535**
Science Fund for Emerging Distinguished Young Scholars	NSFC	researchers under 38 years old to work in academia (d)	2011	**2398**
Ten Thousand Talent Programme	CLGCTW	To support high-end talent residing in China (d)	2012	**3454**
New Hundred Talent Programme	CAS	Renewal of Hundred Talent Programme (d & I)	2014	**n.a.**
Young Cheung Kong Scholar Program	MOE	Endowed professorships for young scholars at Chinese universities (d)	2015	**440**

1) Abbreviations:

MOE	Ministry of Education	CAS	Chinese Academy of Science
NSFC	National Natural Science Foundation of China	SAFEA	State Administration of Foreign Expert Affairs
CLGCTW	Central Leading Group for the Coordination of Talent Work		I = International focus d = fomestic focus

Source: Cao et al. 2019

Cao et al. roughly approximates that by 2018, about 16,000 scientists and technology entrepreneurs could be brought back through central government programmes (Cao et al. 2019) . The above table by Jonkers et al. (2019) shows a sample of central government programmes. Many programmes have been

running for a long time, but it remains unclear how effective these programmes are in bringing back Chinese or recruiting foreigners. In addition, there are a variety of local programmes, for example in Guangdong province (see chapter 5.3.4), which also provide substantial funding, for which no overview is available.

Li and Tang 2019 conducted a detailed analysis of the Chang Jiang/Cheung Kong Scholars programme, which is aimed at young professors and reports a total of 1,447 participants. They found that the international experience had a mixed impact on career opportunities in China: While the experience hardly makes a difference for young candidates, the time abroad slows down further development in China for "late-stage-careers". They attribute this to the lack of important personal contacts at the local level in China during this time. (Cao et al. 2019) .

Textbox 7: 1000 Talents Programme

An important programme that both attracts international scholars to China and brings Chinese scholars back to the country is the 1000 Talents Programme. It was introduced in 2008 and has supported about 7,000 academics and entrepreneurs by the beginning of 2018. (Jia 2018) . The programme provides incentives in the form of significantly higher-than-average salaries and additional support for foreign researchers, for example in finding accommodation, moving to China, travelling to the home country, and finding jobs for the accompanying partners. (Jia 2018) . The prerequisite for applying for the 1000 Talents Programme is a firm commitment from a Chinese university for a position lasting three to five years. Applicants who have studied at renowned universities and have already published several papers have particularly good chances. In principle, Chinese academics up to 55 years of age can apply; foreign applicants must be under 65 years of age. (Jia 2018) . This age limit was introduced to prevent emeritus foreign professors from participating in the programme. Many young, international scientists value the 1000 Talents programme as a springboard for their own careers. For example, a researcher from Costa Rica who was working at the Max Planck Institute when he applied to China:

"I had just turned 33 when I first heard about this opportunity. The chance to build a lab like this while you are still relatively junior, with access to all these top-notch scientists [at CAS], is what made it so attractive." (Mervis 2019)

At the MPI, he estimates that it would have taken him ten more years to become head of a research group. Some Europeans and Americans express concern that academics and entrepreneurs are being poached by Chinese institutions and that the 1000 Talents programme is thus acting as an instrument of espionage. (Mervis 2019) . Other experts, however, describe the programme as very similar to European research grants that also attract international scientists. Spanish geneticist Jose Pastor-Pareja, who has been working under the 1000 Talents programme at Tsinghua University since 2012, compares the programme to Marie Skłodowska Curie actions under Europe's Horizon 2020. Pastor-Pareja comments:

"It's ridiculous to see it labelled as a quasi-terrorist organisation designed to steal things. [...] It's just another way to recruit talent." (Mervis 2019)

Another example of the desired international opening is the International Young Scientist Fellowship programme administered by the National Science Foundation of China (NSFC), which is aimed at foreigners and for which an application can be submitted in English (as a rule, applications for internationally open programmes can only be submitted in Chinese) (Interview 2019).

One of the goals of the far-reaching reform of the Chinese Academy of Sciences (CAS) in recent years was to increase the internationally recruited staff from 1% to 3%. Currently, 88 members of the Academy are foreigners and 771 are Chinese. However, this does not refer to the scientific staff. At the end of 2018, the Max Planck Society, which is comparable to the CAS, had 31 % non-Germans among

its total staff and 52 % of its scientists* had a foreign nationality. (Max Planck Society 2019) . This planned step for the CAS and the reality in the MPG show that the desired internationalisation of Chinese science is still at a low level.

Textbox 8:Chinese Academy of Sciences President's International Fellowship Initiative

The Chinese Academy of Sciences (CAS) offers numerous international fellowships under the name "CAS President's International Fellowship Initiative (PIFI)". PIFI is one of the important mobility programmes in China to enable international scholars to work or study at CAS institutions. It also aims to strengthen the collaboration of high-level international scholars with Chinese researchers at CAS institutions. The initiative is divided into four programmes, each targeting a specific group: renowned scholars, visiting professors, post-docs and international PhD students. (Chinese Academy of Science (CAS) 2016) .

- Renowned academics, mostly professors, are invited to give lectures at at least two CAS institutes in China and to employ at least one CAS post-doc for one to three months in their home department. All costs for the post-doc and the travel abroad will be covered. For the lectures in China, including travel expenses, meals, hotel and honorarium, 50,000 RMB (approx. 6,700 EUR) per week will be provided.
- Visiting professors, at least titled assistant professor, are employed for two to nine months at a CAS institution to work on a cooperative project. Salaries vary from 20,000 to 40,000 RMB per month (approx. 2,700-5,300 EUR) depending on the professorship.
- Post-docs can apply to conduct research at a CAS-affiliated institute for one to two years. Participation in the programme is remunerated with 200,000 RMB (approx. 27,000 EUR) and travel expenses are covered.
- Furthermore, PIFI supports 200 international doctoral students annually who are doing their doctorate at CAS universities. The programme covers the tuition fees and supports the students financially. (Chinese Academy of Science (CAS) 2019) .

Despite the greater openness and the underlying goals and instruments, in practice it is still often the case that foreign researchers, students or postdocs are in some ways at the bottom of the range of opportunities for action and funding in China. In relation to the size of the system, there are rather few, often very specific programmes for foreigners. These programmes are at the national level as well as at the local or provincial level, such as: Shanghai Pujiang Program, Shenzhen Kongque Program, Guangdong Zhujiang Program, Zhejiang 1000 Talents Program, 3315 Plan of Ningbo and Rising Star. These programmes are hardly known in the foreign community. The talent development programmes are often barely recognisable as talent mobility funding programmes, mostly to be applied for in Chinese and the application to be defended in Chinese (mere translation does not help). The regulations, application processes and evaluation criteria are unclear. Personal contacts or networks are often necessary for a successful application (Interview 2019).

Foreign students can only study at universities that have a corresponding programme for foreigners in the form of an International School. Only these universities are paid by the state for the places they offer (Interview 2019). There, the foreigners are among themselves. Structurally, integration into "normal" degree programmes is hardly possible. In addition, the university staff is often unable to communicate clearly with the foreign researchers and students due to their lack of English language skills and the foreigners' lack of Chinese language skills. Intercultural competence on both sides would be helpful to enable efficient communication (Interview 2019).

Furthermore, foreign scholars do not have the opportunity to participate in important project funding programmes in China. At the same time, the obstacles associated with visas and employment for

foreigners in China make mobility problematic for foreigners. In addition, the current Chinese legislation for non-governmental organisations puts obstacles in the way of non-profit foreign actors in China (for example, also the DFG or the Fraunhofer Gesellschaft).

Despite the above-mentioned positive figures for returnees and individual examples of successful foreign academics, it remains unclear what significance the various state programmes actually have on a broad scale and whether the international programmes for students really drive the internationalisation of universities or whether they are niche products. German students report that they have hardly any contact with Chinese students and are essentially in a society with other foreigners (Interview 2019).

3.3 Entrepreneurs hip

The basis for the development of the start-up scene is, among other things, the Torch programme (see chapter 5.2.1). Companies that set up in the Torch centres receive, for example, tax breaks, special training, premises, rent reductions, funds for research and development, and financial support for market-oriented science projects from the MOST (Schuman 2016; Abele 2019b) . In these high-tech zones alone, about 1000 companies are established every day (Abele 2019b) .

3.3.1 "Venture Communism"

The New York Times described the Chinese government's heavy involvement in national entrepreneurship as "venture communism" in September 2016. (Schuman 2016) . Through state venture capital guidance funds, the government participates in private and state venture capital firms and their risk hedges. According to the Financial Times, the Chinese government has thus provided thousands of venture capital funds with about 1.8 trillion USD (about 12.6 trillion USD) by 2018. USD (about RMB 12.6 trillion) to thousands of venture capital funds by 2018, influencing market development. (Feng 2018) . The government controls the areas in which companies are to receive particularly strong support and clearly focuses on technology-based industries, such as artificial intelligence, electromobility, robotics, big data, modern communication technologies and biotechnology. Experts see China as being particularly ahead in the field of artificial intelligence. In 2017 alone, for example, 48 % of the venture capital invested in artificial intelligence worldwide flowed to China. (Abele 2019b) .

In 2017, the government published for the first time a guide that advocates entrepreneurship and innovation. Specifically, the government here advocates entrepreneurship that establishes hard work, the pursuit of excellence, craftsmanship, innovation and social responsibility. In the guide, the government also emphasises protecting the rights of entrepreneurs, ensuring fair competition in the country, as well as strengthening intellectual property protection to promote innovation. (Fan 2017) . Meanwhile, the atmosphere in Chinese start-ups is similar to that in tech companies in Europe or the USA. (Bölinger 2018) .

Entrepreneurship and start-ups are also strongly promoted at universities in China. Certain platforms are designed to give students the opportunity to try out innovative ideas, to exchange ideas and, if necessary, to set up companies. The X-Lab at Tsinghua University in Beijing offers such a platform and invites students, faculty, alumni, entrepreneurs, investors and experts to exchange ideas and work together. (Tsinghua University 2019) .

3.3.2 Incubators and accelerators

In addition, there are now thousands of incubators and accelerators in China that accelerate start-ups. The biggest difference between them is that accelerators drive the development of an already existing start-up, while incubators support the path from an innovative idea to the founding of a company. (Hoyt 2017) . Accordingly, accelerators focus on companies, incubators on innovations. According to an evaluation by GTAI, there are about 4,000 Technology Business Incubators (TBI) in China. (Abele 2019b) . Some of the largest incubators and accelerators are located in Beijing's Zhongguancun Park, the Silicon Valley of China. (Huang 2019) . A high density of talent, investors, incubators and

accelerators, as well as government support, ensure that there are about 9,000 high-tech companies in this district alone, including the corporations Baidu and Sina (Jing 2018) . Some of China's "Unicorns" (see below) have also emerged in Zhongguancun, such as ByteDance and Didi Chuxing. China's elite universities Beijing and Tsinghua with their science parks are also located in Zhongguancun. Other start-up strongholds are in Shanghai, Hangzhou and Shenzhen. (Hoyt 2017) .

3.3.3 China's "Unicorns"

The rapid development of Chinese start-ups also becomes clear when one considers the high number of so-called unicorns or "unicorns". These are privately owned start-ups that are worth at least one billion USD (approx. 7 billion RMB). Well-known international examples are the ride-hailing service *Uber* or the accommodation provider *airbnb.* (CB Insights 2019) . The development of Chinese unicorns is enormous. While almost 50 % of all unicorns worldwide come from the USA, almost a quarter already come from China. (German 2019) . According to *CB Insights, there are* currently around 400 unicorns worldwide (as of September 2019), 89 of which are from China (CB Insights 2019) . The largest Chinese unicorns are Ant Financial (Alipay), Bytedance, and Didi Chuxing.

However, the figures from different sources vary widely and seem to change rapidly. Once a company goes public, it is no longer a unicorn, but still an essential company for the economy, contributing to technological and innovative progress.

Table 7: China's Top Unicorns 2019 (as of October 2019)

Rank	Company (Headquarters in China)	Value (in US$ and RMB)	Area
1	Ant Financial1) (Hangzhou)	US$ 150 billion (approx. 1050 billion RMB)	Fintech
2	Toutiao (Bytedance) (Beijing)	US$ 75 bn (approx. RMB 529 billion)	Artificial Intelligence
3	Didi Chuxing (Beijing)	56 billion US$ (approx. 395 billion RMB)	Transport sector; car-hailing
4	Kuaishou (Beijing)	US$18 billion (approx. RMB 127 billion)	Mobile and telecommunications
5	DJI Innovations (Shenzhen)	15 billion US$ (approx. 106 billion RMB)	Hardware

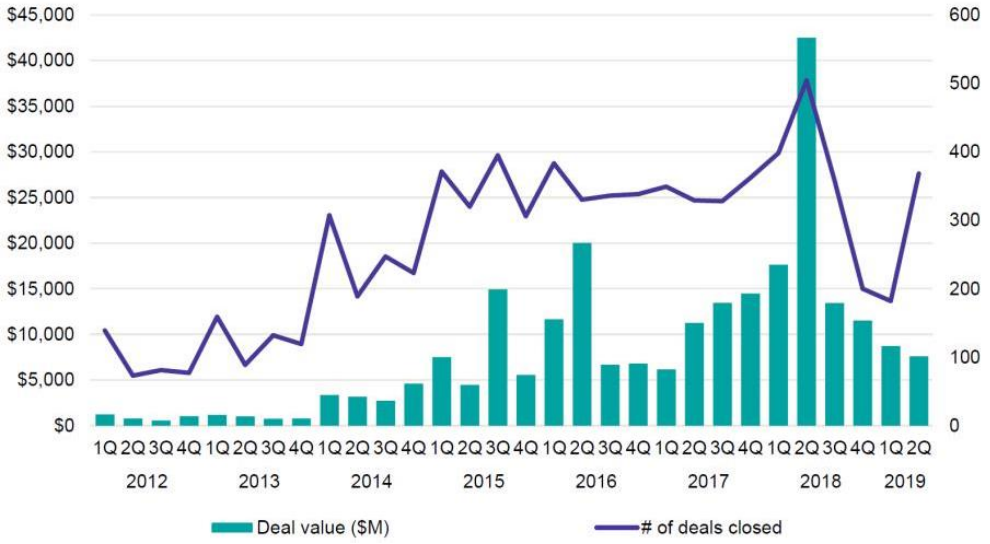
1) Ant Financial is part of Alibaba. Alibaba is listed on the stock exchange and is not a Unicorn. Thus Ant Financial is not a clearly associated unicorn, but is often counted as one. (Xinhuanet (新华网) 2019)
Source: Own representation based on data from CB Insights 2019; Abele 2019b, p. 4

3.3.4 Venture capital in China

The establishment of technology-oriented companies is often dependent on venture capital (Schefczyk 2015) . Venture capital is "the participation of an investor in a start-up/young company that needs capital for its growth“. (Federal Ministry of Finance (BMF) 2018, p. 30) . Venture capital is a "sub-form of off-market equity capital" and can be private or state-owned. (Stresing et al. 2018) .

Venture Pulse Q2 2019 - Global analysis of venture funding, published by KPMG Enterprise, examines key trends and opportunities in the global venture capital market. Figure 24 shows venture investment in China from 2012 to mid-2019. While the number of venture capital activities has increased significantly again since the end of last year, the value of investments has decreased slightly. KPMG Enterprise interprets this development with caution, warning that such a jump may well be followed by a decline in investment in the next quarter (Q3) (KPMG Enterprise 2019) .

Figure 24: Venture financing in China (2012-2019)



Source: KPMG Enterprise 2019 , S. 93

China has only seen relevant venture capital investment since 2014. The growing start-up spirit in China is due to the risk appetite of the Chinese, but also to the start-up support of the government. It is becoming increasingly easier for university graduates to found and register companies, for example by providing free premises for founders. (Shi-Kupfer and Ohlberg 2019) . This trend is also reflected financially: from 2015 to 2017, the amount of investment in venture capital increased by 25%. This is the fastest venture capital growth in the world. (Florida and Hathaway 2018) . China has also caught up strongly compared to the EU or the USA. Current figures for a concrete overview of venture capital investments vary greatly in different studies, so that only indicative values can be given. While China invested only about USD 5.6 billion (approx. RMB 39.2 billion) in 2010 according to Forbes, the value in 2018 was about USD 105 billion (approx. RMB 735 billion). In the US, the value increased from USD 30.8 billion (approx. RMB 216 billion) to about USD 111 billion (approx. RMB 777 billion) in the period. (Fannin 2019) . According to KPMG, China's value in 2018 was about USD 85 billion (about RMB 595 billion) the value of the US was as high as USD 130 billion (about RMB 910 billion) . (KPMG Enterprise 2019) . This means that China is close on the heels of the USA. In Europe, the value in 2017 was only EUR 15.6 billion (approx. USD 17.2 billion or approx. RMB 120 billion). (German Bundestag 2018) . Compared to China and the US, the EU still has some catching up to do. The EU seems to have realised this development and has announced that more capital will be invested in innovative startups in the future (Federal Ministry for Economic Affairs and Energy (BMWi) 2018) .

3.4 Conclusion on the actors in the R&I system

China's development of the education system has led to strong academisation and a large number of young graduates. These form a large pool of manpower for research and technology. While there is still a high demand in the technology fields and graduates quickly find jobs in industry, there are also growing problems with adequate jobs for graduates in other subjects. Many graduates are not educated well enough or fit enough to provide sufficient expertise to achieve the state's goals. The Chinese government has to manage the balancing act of avoiding graduate unemployment on the one hand and training well-qualified experts and recruiting them internationally on the other.

China has been successfully using sending talent to build expertise for China's development for many years. Germany also takes in a great many Chinese students. The current discussion in the US (or even in Australia) about the dangers posed by Chinese is not directly transferable to Europe. Europe is by far not as intensively interdependent as China and the USA. But in Europe, too, it should be examined

whether and how greater benefits can be obtained for the host countries and risks minimised.

China has become a destination for student mobility and also scholar mobility. Especially students from Africa and BRI-associated countries are supported with Chinese scholarship programmes. But 5.6 % of German international students also went to China in 2016. From a German perspective, the improved conditions in China should be further exploited. It would be in the interest of Germany's own innovation development if more students and scientists found their way to Chinese universities and laboratories. There seem to be many suitable programmes, but the path is often not transparent. As far as is known, the impact of studying in China on the career opportunities of German graduates is not tracked. It may be useful to analyse the current experiences of German students and to examine and possibly expand the existing support services. At the same time, it should be monitored more closely how well international students are actually being educated in China across the board, regardless of pure enrolment figures.

China has a variety of programmes to encourage Chinese professionals to return to China. The figures on effort and impact are patchy. Nevertheless, it is clear that returnees play an important role in China and that a return is attractive for more and more Chinese, as Chinese companies offer better working conditions and opportunities for advancement. This creates opportunities for returnees from Germany and also the risk of a knowledge drain. It is in the interest of the German innovation system to open up career options for the talents trained in Germany in German firms and institutions or Chinese firms in Germany. At the same time, Germany can also benefit from returnees to China who make new contacts with Germany possible in the first place. German companies and research institutions need talent, both students and employees. An analysis of the current career paths of Chinese graduates in Germany may be a first step towards developing suitable instruments to make the best possible use of opportunities.

For Germany as a location for innovation, broad China competence and Chinese language skills are necessary. This current situation should be optimised. More people study Chinese in France than in Germany.

Over the past two decades, the startup and entrepreneurial scene in China has grown significantly. This development strengthens the expansion of advanced technology as well as economic growth (Tse 2016). The Chinese government supports this development and encourages startups through financial and structural support. These are also sometimes open to foreign founders. This may be interesting for German founders in individual cases.

4. Performance of the innovation system

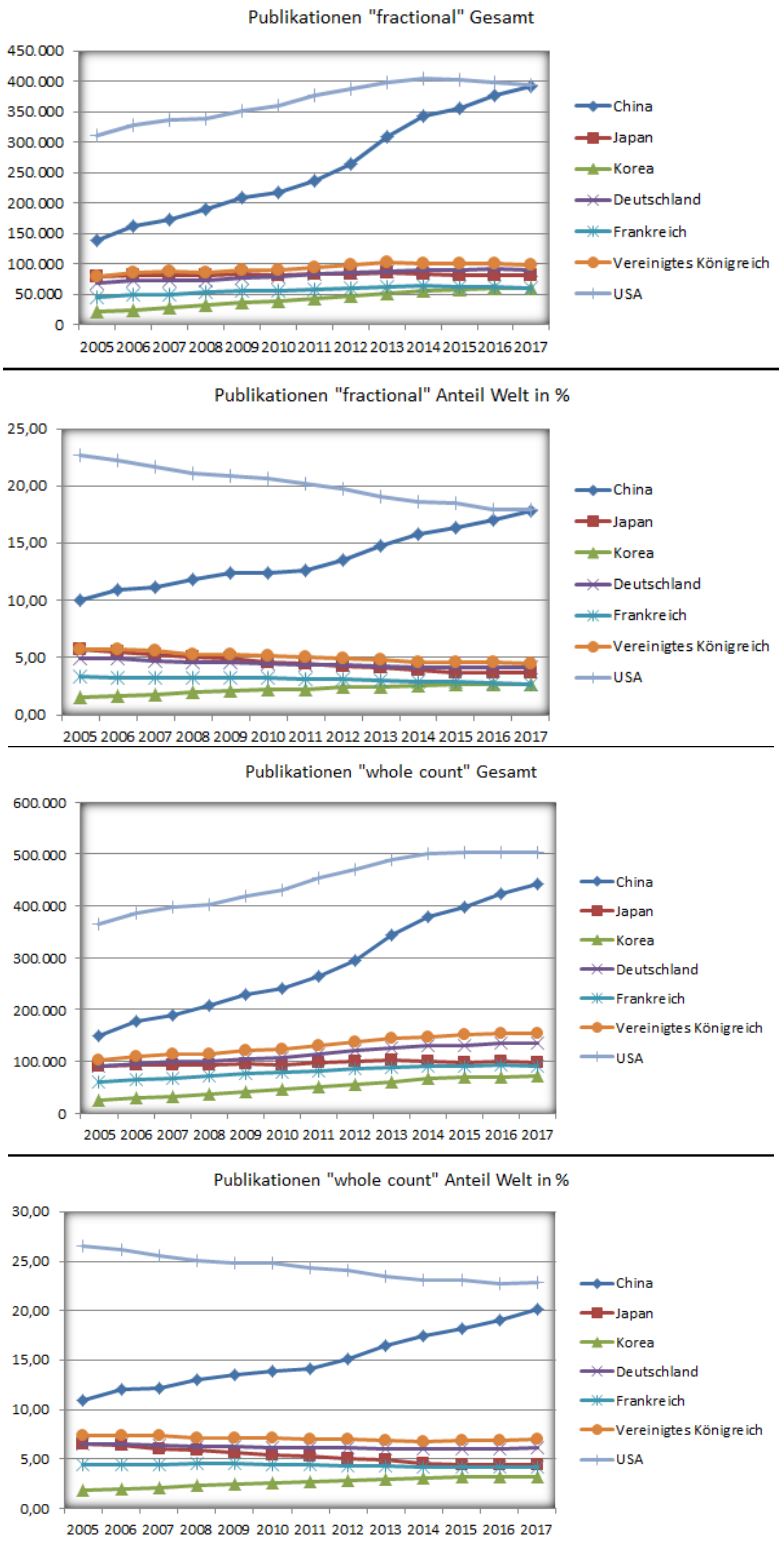
China's declared goal is to become the world leader in science and technology by the middle of the 21st century. China's size and dynamism require its own Chinese innovations for this.

The impact of China's policy so far can be indirectly deduced by looking at available output indicators. According to these, after rapid development, especially in the last 10 years, China has now assumed a leading role worldwide in some technology areas (e.g. Figure 3, Figure 25, Figure 29).

Indicators for the results of research activity are measured indirectly. Established indicators are publication activity as the results of scientific work and the registration of patents as the results of application-oriented research. The impact of research on the innovation system is more difficult to determine. It is described approximately by the citation of publications or could also be measured, for example, by patent utilisation figures. The presentation of the publication and patent utilisation figures in the following is essentially based on the data compiled by the Fraunhofer-ISI, GIGA and DAAD as part of the BMBF's commission to monitor the Asia-Pacific research landscape, and which is available for further evaluation. (Frietsch et al. 2018a) .

4.1 Publications

Figure 25: Publications "fractional" and "whole count", Total and as a proportion of the world (2005 - 2017)[1)2)]

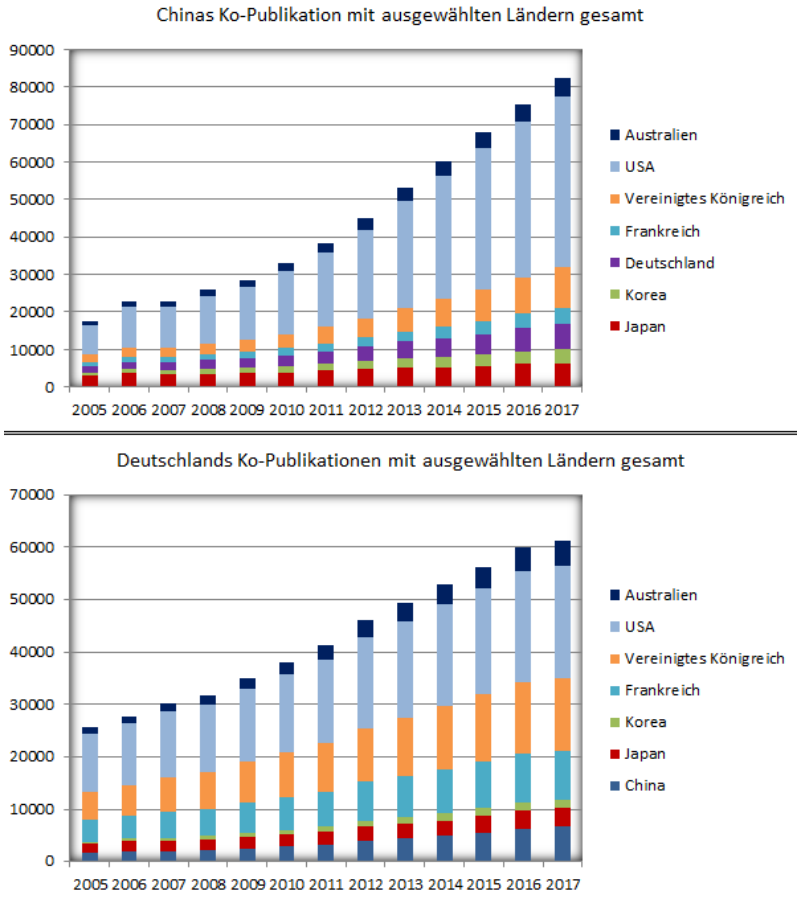


1) Publication trends that can be assigned to individual countries via the authors' addresses2
) "Whole count": all authors of a publication are credited with 1 to the country of origin (in the case of 4 authors from 4 countries, each country receives 1); "Fractional count": each publication counts as 1 and authorship is calculated proportionally (in the case of 4 authors from 4 countries, each country receives 0.25 credit).
Source: own representation based on adjusted SCOPUS data, Frietsch et al. 2018a

China and also the competitor countries under consideration are developing positively in terms of absolute publication figures. China shows the already described stronger increase over the last few years. In the fractional count, China caught up with the USA in 2017. Accordingly, China's rise is also visible in the share of Chinese publications in the global publication volume. China has now reached a global share of about 18 % in the fractional count, while the American share (also about 18 %), or even the British and Japanese shares, have visibly declined within 12 years. Germany's and France's share is comparatively stable, Korea's relevance is increasing. While there have been signs of a certain stagnation in most of the countries considered since around 2014, no flattening of the curve can be observed in China. In this respect, the development process, similar to Korea, is obviously not yet complete.

China's publication numbers are artificially boosted by a strong reward system and, at least in some universities and provinces, also premium system, and the quality of many articles is not high (Huang 2018) . While this is relevant, it should not distract from the fundamental actual research performance evidenced by publications and citations. That not only the absolute number of publications is increasing but also the quality is shown, for example, by the excellence rate in Figure 28.

Figure 26: Co-publications in China and Germany, together with selected countries, total1)



1) Presentation of co-publications: The authors' countries of origin are shown for publications with authors from different countries.
Source: own representation based on adjusted SCOPUS data in Frietsch et al. 2018a An examination of co-publications over time comparing Germany and China with major competitor countries shows that both countries have expanded their international cooperation over the last 12 years, China 4-fold, Germany 2½-fold.

The US and China have established a very close relationship in research, which also has a certain dependency as a result. China's co-publications are very concentrated in the US with almost 2/3 share. Co-publications between China and the USA also show a larger increase than between China and the EU. In addition, three times as many Chinese researchers go to the USA than to EU member countries.

(Publications Office of the European Union 2019) . Nevertheless, among the countries considered, Germany is China's third most important cooperation partner after the USA and the United Kingdom, together with Japan. Even though other countries were not considered here, this ranking also applies worldwide.

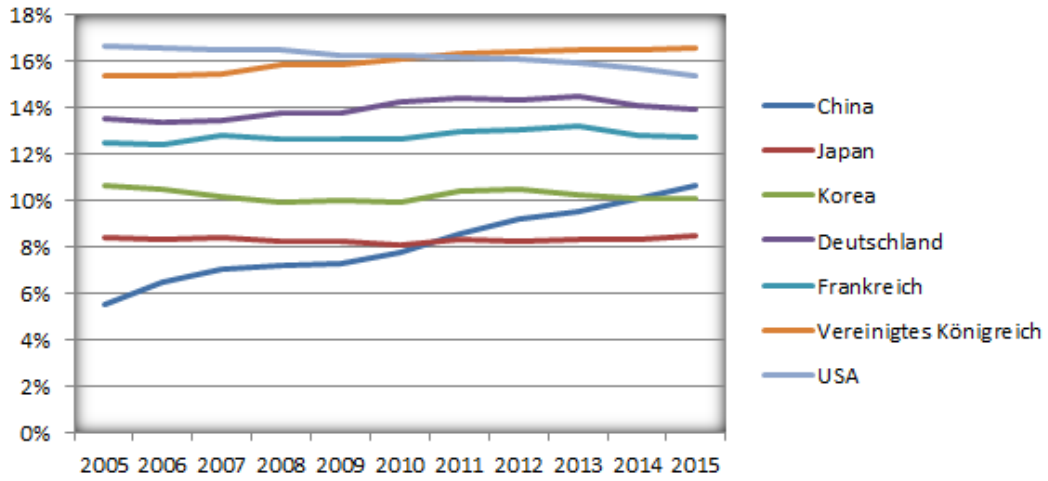
Germany is more balanced in its scientific co-publications. Increases with China are offset by even higher increases with the United Kingdom and France or even the USA. Nevertheless, China has developed increasing relevance for Germany in recent years and is now visibly ahead of Japan and Australia in fourth place among the countries considered.

Quality of the publications

The common way of making statements about the quality of research is the number of citations of publications. This looks at how often a publication has been used by other authors. The so-called excellence rate refers only to the most cited publications sorted by subject area and shows the change in the quality of research results independent of the size of the system under consideration. For example, the quality of research from a large and a small country can be compared.

About 14 % of the research papers published with German participation are among the most cited publications in the respective subject. Compared to the other countries considered, Germany is thus a good research location and has been stable over a long period of time.

Figure 27: Excellence rate of publications (2005-2015)[1)]

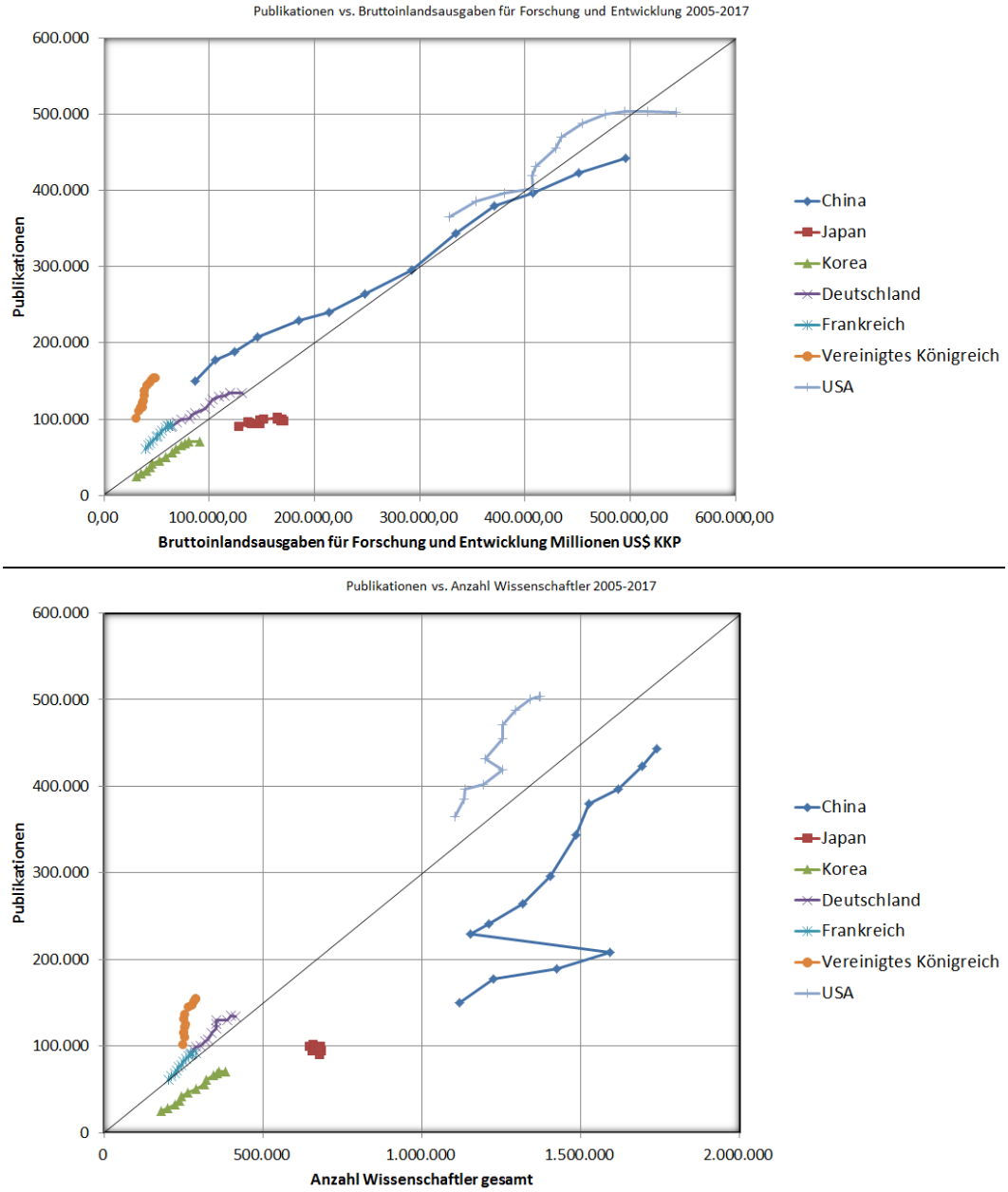


1) Publications that are counted among the 10% most highly cited publications ("whole count") in a research field and year, in each case as a percentage of the total number of citations in this field and year.
Source: own representation based on adjusted SCOPUS data in Frietsch et al. 2018a

Figure 28 confirms the statement made above that the quality of China's research output is improving rapidly. Since 2015, China's excellence rate has been higher than Korea's and Japan's and there is no sign of the curve flattening. While the UK's excellence rate is also rising, and those of Germany, France, Japan and Korea are largely stable, the US's excellence rate is falling.

For a comparative system description, it is helpful to attempt to depict the resources flowing into a system and the system outcome. In relation to the scientific part of the innovation systems of China, Germany, Japan, Korea, the USA, France and the UK, this is illustrated in Figure 29 by the combination of publications and R&D expenditure or by the combination of publications versus the number of scientists in the countries.

Figure 28: Comparative representation of the indicator's publications, R&D investments and number of scientists* (2005-2017)



1) Input-output representation of the innovation system of selected countries over time using the indicators publications ("Whole Count") vs. R&D investments (top) and publications vs. number of scientists (bottom). The individual data points refer to the situation of one year with a progression from 2005 to 2017.
Source: Own representation based on OECD 2019b ; Frietsch et al. 2018a

Figures 28 show how efficiently the UK translates a fairly small budget increase into publication output and how little a budget increase in Japan leads to an increase in publications. China has made great leaps in recent years, achieving an increase in publications along with the increase in R&D expenditure, and to a similar extent as in France, Germany or Korea, but with much larger jumps in both indicators from year to year. Over many years, China has thus managed both to enable continuous large budget increases and at the same time to develop a sufficient number of scientists from the education system who, in suitable, rapidly established research structures, also produce a corresponding output with the money. China's budget and publication output has reached the level of the USA.

Since "whole count" figures are used here, effects such as the artificial expansion of authorship or also the low quality of publications certainly play a role. However, these effects are not the main driver of

the development.

In the past four years, there are indications in Germany and Korea, and very visibly in the USA, that the budget continues to rise, but not the number of publications. This effect should be investigated together with the curve of Japan, as it is possible that marginal utility or marginal productivity of the science system is being reached here.

Looking at the relationship between the number of researchers and publications at the bottom of Figure 29, a similar picture emerges. The UK is efficient, Japan is stagnant, France, Korea, Germany and also the USA are roughly on a similar line, indicating similar researcher productivity. The productivity of researchers in the UK seems to be higher than that of the other countries and the productivity of researchers in China and Japan seems to be lower. At this point, the gap between the curves of China and the USA does not close either.

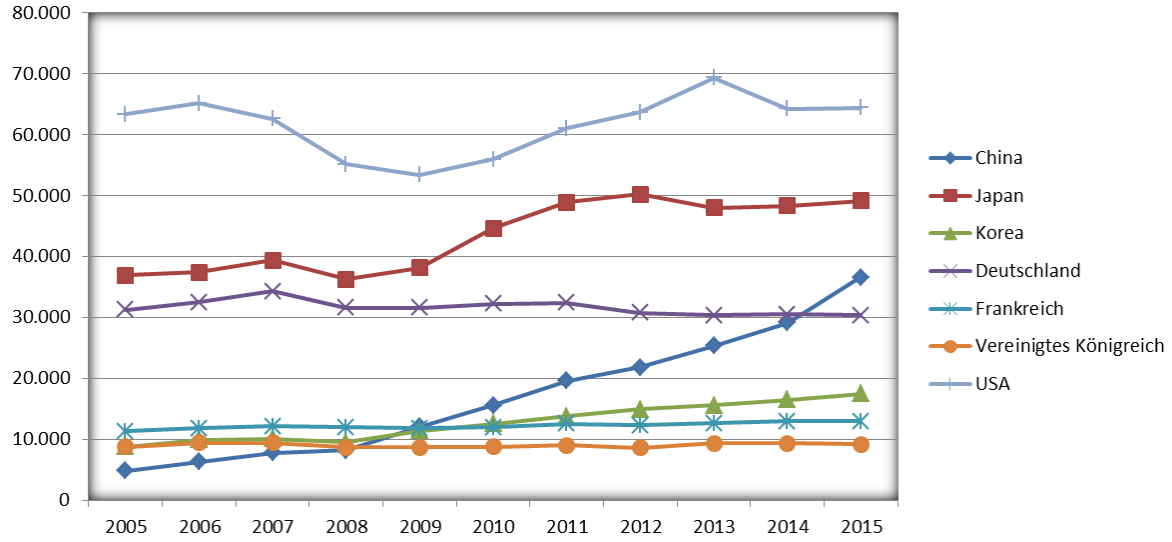
German scientists are productive with high quality and broadly positioned in their international cooperation. Germany is a relevant research location worldwide and stable in its performance record. It is a generally accepted statement for Germany's knowledge economy that scientific cooperation with strong science nations such as the USA, Great Britain or Japan is an obligation in order to participate in the best possible way in global knowledge production. This understanding should apply in the same way to China, now by far the world's second most important research nation, which has also quickly caught up with the leading research nations in terms of research quality and continues to develop positively. If we take the United Kingdom as a guide, because development with the USA is an inappropriate comparison for Germany, Germany's co-publication development with China lags somewhat behind (Figure 26 above). If it is assumed that China now has a similar importance to the USA - and this is what Figure 25 says - Germany's co-publications with China should actually be oriented towards Germany's co-publications with the USA.

The result of the indicator analysis is the recommendation to strengthen German cooperation efforts with Chinese partners. To do this, one must take a closer look at the subject areas in which German forms of cooperation lag behind those of other nations and examine whether an expansion of cooperation in the respective subject area would be advantageous for Germany. In areas where advantages are seen, cooperation should be expanded in a long-term, systematic and relevant manner. The input-output analysis indicates a marginal benefit in the science systems. Higher investment does not seem to lead to higher productivity. At the same time, the UK figures suggest an improvement in productivity without high additional investment. The correlations could be looked at more closely.

4.2 Patents

Patents are important indicators for showing the success of an innovation system (Federal Ministry of Education and Research (BMBF) 2018b) . China issued a national "IP strategy" as early as 2008 and has continuously adjusted the existing patent laws, most recently in early 2019. This was followed in 2010 by a national patent development plan (ChinaPower Project 2019) . The associated government incentive mechanisms for applicants to expand patent applications are having an effect: the number of Chinese patent applications has risen continuously both internationally and at the Chinese National Intellectual Property Agency (CNIPA, formerly SIPO) in recent years. The number of China's transnational patents (*"patent families with at least one application at the European Patent Office (EPO) or at the World Intellectual Property Organization (WIPO) under the Patent Cooperation Treaty (PCT)") has increased between 2006 and 2015.* (Frietsch et al. 2018a, p. 88)) increased at an annual growth rate of 22.3% between 2006 and 2015. In 2014, China overtook Germany, leaving the US, Japan and the EU with more total transnational patent applications than China. With a share of 30 % of all transnational patents in China, applications in the fields of computers, electronics and optics are a particular focus. (Publications Office of the European Union 2019, p. 60) .

Figure 29: Representation of transnational patent applications (2005-2015)



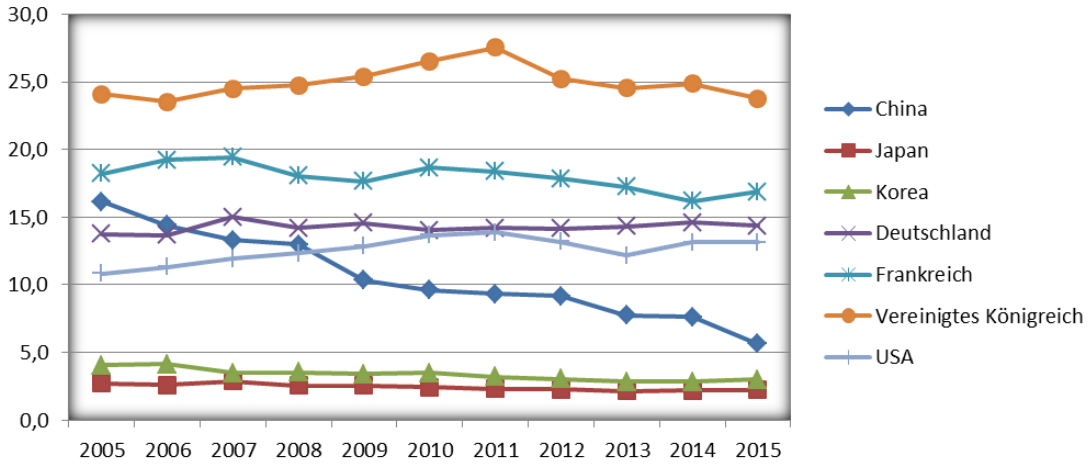
Source: own representation based on adjusted EPA - PATSTAT data in Frietsch et al. 2018a

The developments of the international patent applications of France, Germany and the United Kingdom have been stable for many years. Apparently, the higher R&D investments or even the higher numbers of scientists in Germany, for example, or the expansion of international research cooperation have no significant impact on patent applications. So if patent application numbers make a statement about a country's innovative strength, it seems to be stable in the three European countries, but not increasing. China's international patent applications have been rising steadily over the 10 years under consideration. At least until 2015, there is no sign of China's curve flattening. A relatively high share of Chinese applications, both at the transnational level (7.9 percent) and especially at the CNIPA (23.1 percent), are filed by public research institutions and universities. Technologically, Chinese applications are concentrated on information and communication technologies and consumer goods (Frietsch et al. 2018, p. 90).

Co-patents

The representation of transnational co-patent applications in Figure 31 shows a descending trend in the filing of co-patents with China. This expresses the increasing technological strength and independence of Chinese firms, which are gaining weight in international markets, and the decreasing relevance of joint ventures with foreign firms. All other countries remained largely constant in their patent filing behaviour in terms of cross-border cooperation, with the Europeans and the USA comparatively well above the figures for Japan and Korea. Apparently, the need for cross-border cooperation is lower in Asia. The development in China may therefore also be seen as a consolidation based on national needs and driven by national companies, which is typical for Asian countries.

Figure 30: Share of co-patents in transnational patent applications (2005-2015)[1)]



1) Figures in %.
Source: own presentation based on adjusted EPA - PATSTAT data in Frietsch et al. 2018a

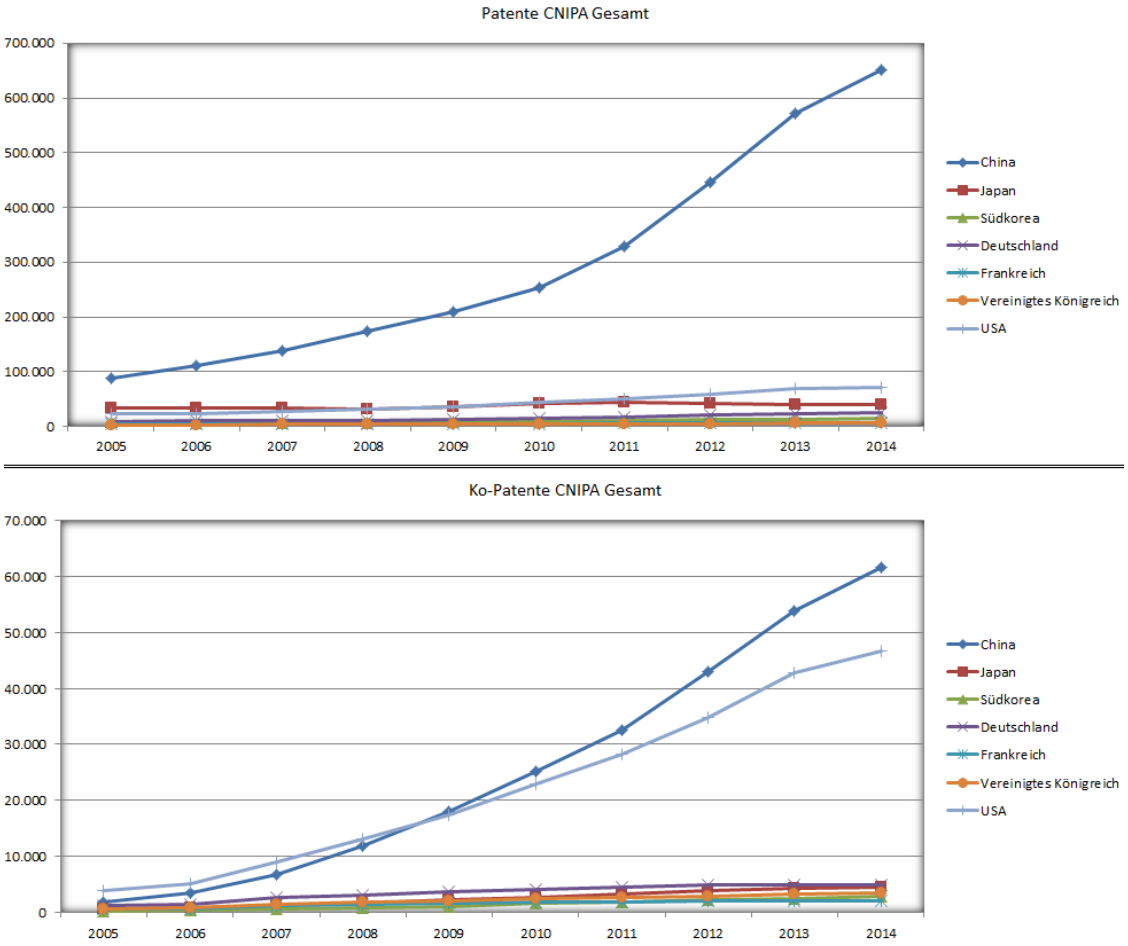
When presenting the filing of patents and co-patents at the national level at the Chinese patent office CNIPA, the quantitative growth becomes even clearer than in the case of international applications.

The transformation of the State Intellectual Property Office (SIPO) into the China National Intellectual Property Administration (CNIPA) is, according to Frietsch, a signal that the transition from the phase of imitation to innovation should be accompanied by an authority with more decision-making rights for stricter supervision of the observance of intellectual property rights and more central government funding. (Frietsch et al. 2018a, p. 56) .

"At the national level at CNIPA, patent numbers have exploded in the years since 2008. While foreign applicants slightly more than doubled their filing numbers between 2008 and 2014, Chinese inventors increased their patent output by about four times. They filed about 650,000 patents nationally in 2014, out of a total of 780,000 applications at the Chinese Patent Office." (Frietsch et al. 2018a, p. 88)

Actors from other countries co-file patents with Chinese in China comparatively rarely. It appears that almost all co-patent applications at CNIPA are agreed between Chinese and US actors. Other countries are marginally involved. Here, as in the case of scientific work, a high degree of dovetailing between Chinese and US actors is evident.

Figure 31: Patents and co-patents filed with CNIPA



Source: own representation based on adjusted EPA - PATSTAT data in Frietsch et al. 2018a

The development of patent applications both internationally and nationally indicates that actors in established industrial locations seem to have been applying for a stable number of patents for several years. Only China and Korea show significantly increasing application numbers. Despite the rising number of patent applications, China sees a need to catch up even in the quality of patents in order to reduce the current dependence of the Chinese economy on foreign patents. China's catching-up is also still quite recent and older patents relevant to many technologies are held by foreign companies. Between 2008 and 2017, China had to acquire patent rights from abroad for USD 185.2 billion (approx. RMB 1.3 trillion), while at the same time Chinese patent uses abroad only generated USD 12.2 billion (approx. RMB 85.4 billion). And of this, almost a third was acquired in 2017, at USD 4.8 billion (approx. RMB 33.6 billion). By comparison, the US raised USD 128.4 billion (approx. RMB 898.8 billion) and Japan 41.7 billion (approx. RMB 291.9 billion) in 2017 (ChinaPower Project 2019) . Greater independence of China from foreign patents will only happen step by step, despite the increase in applications.

4.3 Innovative capacity of Chinese companies

A key question for Germany and other industrialised nations is how innovative the Chinese innovation ecosystem and Chinese companies actually are. Indicators that would enable a comparison are rare and the data basis in China is often unclear, see below. The innovative capacity of Chinese companies is interpreted quite differently. According to Atkinson and Foote (2019), who look at Chinese innovative capacity in competition with the USA, the importance of scientific innovation capacity, in which China has so far only been successful in individual areas, is rated too highly. Chinese strengths lie more in engineering-driven innovation, consumer-oriented innovation and efficiency innovation (Atkinson and

Foote 2019) .

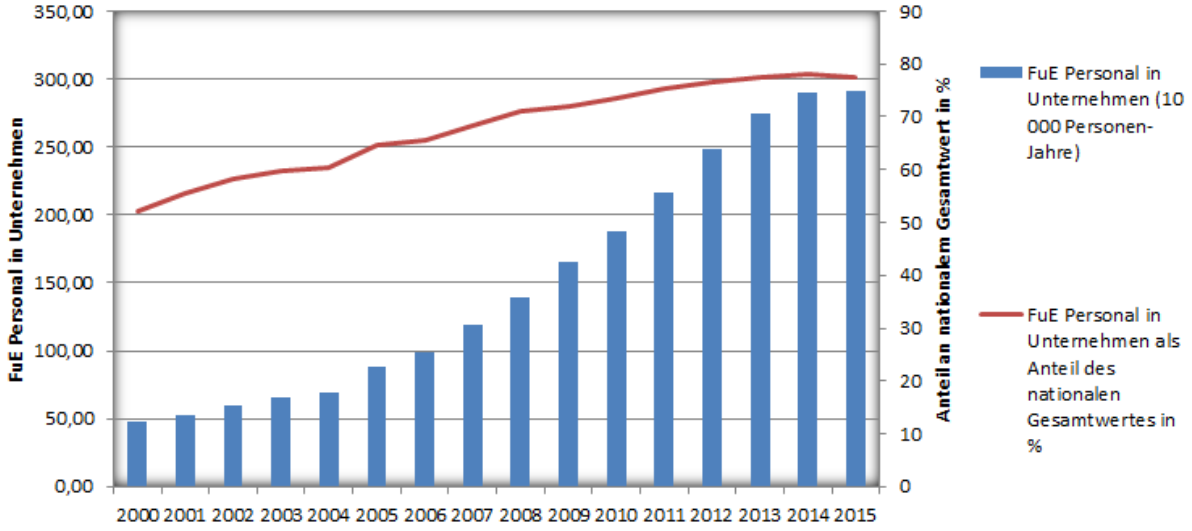
In addition, when considering the role of business enterprises in China, the role of "state-owned enterprises" and their often non-transparent forms of financing and unclear decision-making structures made comparability difficult. It is not only the enterprises that are directly owned by the state, the State-Owned Enterprises (SOEs), but also enterprises that belong to individual party members or their family members or that belong to subdivisions of the state would have to be taken into account. These "state-owned" companies often align their research expenditures and innovation goals with government requirements. They also have better access to financing from, again, state-owned banks, which enables them to invest higher amounts in certain R&D areas (ChinaPower Project 2019) . With this direct and indirect power of the party and government already described above, companies are mobilised to provide money for specific causes, often in technological areas important to the party: '*the state invests heavily in SOEs to enable an edge in certain areas and such companies can burn money and get competitive advantages*' (interview 2019). Market requirements or profitability for the enterprises then come second (Interview 2019).

The innovation capacity of companies in China is monitored by the Chinese Ministry of Research and Technology using indicators and documented in a report published every two years entitled "China Science and Technology Indicators" (most recently in 2018). (Ministry of Science and Technology (MOST) 2018) . In addition, MOST conducts an "Enterprise Innovation Survey" in which 646,000 enterprises are surveyed. (Liu et al. 2018) . It provides an overview of enterprise innovation and includes questions on innovation collaboration and on factors hindering innovation. It also provides an analysis of entrepreneurs' understanding of innovation.

4.3.1 R&D personnel

R&D personnel are seen in companies as an important factor for the company's ability to innovate (Ministry of Science and Technology (MOST) 2018) . The increasing demand for innovation and innovative activity should be accompanied by a steadily growing R&D workforce in academia and companies. In 2015, Chinese companies employed 2.9 million people (full-time equivalent FTEs) in R&D. The employment landscape in China of people in R&D has changed significantly over the past 15 years. Fifteen years ago, about 50% of researchers worked in business and 50% in publicly funded research; currently, almost 80% work in business. (Ministry of Science and Technology (MOST) 2018). There has been an absolute increase in R&D personnel from 500,000 FTEs in 2000 to almost 3 million FTEs in 2015. According to UNESCO statistics, there are a total of 1,740,442 research FTEs in China in 2018. (UNESCO 2019b) . It can be assumed that the Chinese statistics also count technical staff, but this is not clearly defined in the Chinese source.

Figure 32: R&D personnel in Chinese companies and as a share of the national total (2000-2015)



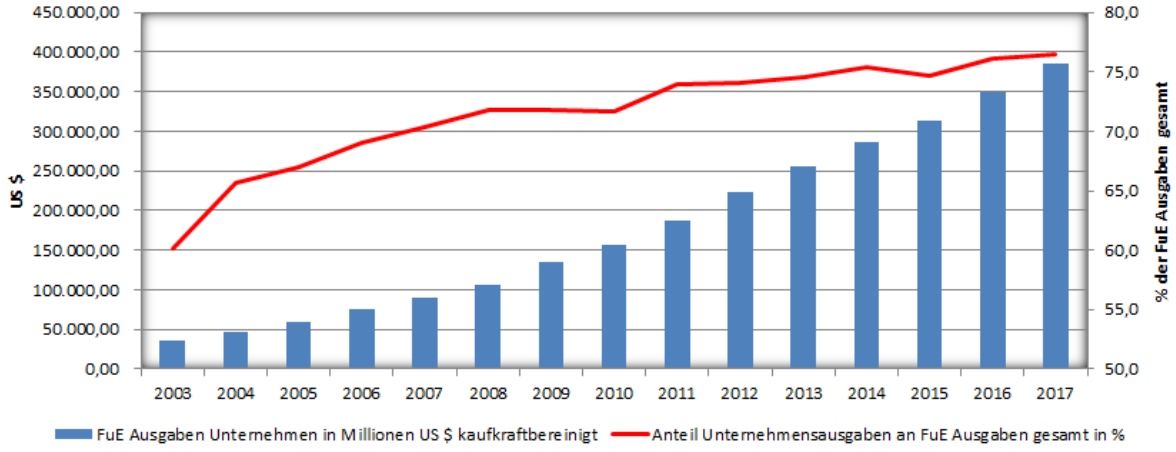
Source: Own representation based on data from the Ministry of Science and Technology (MOST) 2018

Compared to the current 3 million FTE R&D personnel in China (or 1.7 million according to UNESCO figures), German firms employed 404,767 FTE in research in the same year. (Stifterverband 2019) , 132,542 were employed at German universities and 101,005 in research organisations (vs. approx. 600,000 in China in R&D outside companies) (Federal Statistical Office 2019) .

4.3.2 R&D expenditure

Between 2003 and 2017, R&D spending by Chinese companies increased steadily. In 2017, China's enterprises reached R&D expenditures of over USD 380 billion (approx. 2.4 trillion RMB or approx. 350 billion euros). This is a 10-fold increase compared to 2003 in absolute terms. The share of national R&D expenditure has increased from 60.1 % to 76.8 % during the period. This trend emphasises the growing role of enterprises in innovation in China (see Figure 33). In Germany, $91 billion (about RMB637 billion or about €83 billion) was spent on corporate R&D in 2017. This accounts for a national share of 66.1 (OECD 2019b) .

Figure 33: Chinese companies' expenditure on R&D (2008-2017)



Source: Own representation based on OECD 2019b

According to Chinese statistics, the main source of R&D funds in Chinese companies is in-house funds. Between 2010 and 2015, these accounted for 94 % of R&D expenditure, followed by government funding at 4 % and foreign and other funding at around 1 % each, see Table 8. (Ministry of Science and Technology (MOST) 2018) In comparison, a 2017 KfW study for Germany found that 82 % of R&D funding comes from internal resources. 9 % are bank loans, 6 % state subsidies and 3 % other sources. (Zimmermann 2019) . Internal company funds therefore play an even greater role in China than in Germany. However, the ambiguity in the financing of "state-owned enterprises" and their reporting of R&D funds must also be taken into account here. Banks or investment funds are not mentioned as a "source" of financing in Chinese statistics. Yet, for example, as of 2016, according to US data, there were at least 780 "government-linked" investment funds with a capital of 326 billion USD (approx. 2.28 trillion RMB). (Duesterberg 2018) .

It is worth mentioning that the role of R&D funding by foreign countries at a low relevance level has decreased again in relation to total investment. This includes the forced R&D investments of foreign firms in "joint ventures" and also the development of research capacities in the interest of German firms in China, such as that of SAP in Shanghai, or also the establishment of foreign firms with R&D approaches in the technology zones and parks (see Chapter 2).

Table 8: Budget information and composition of expenditures for research and development by companies in China

Category	Source of R&D expenditure	2010	2011	2012	2013	2014	2015
R&D expenditure by source in RMB billion (in EUR bn)	Government expenditure	23,7 (3)	28,9 (3,7)	36,3 (4,6)	40,9 (5,2)	42,2 (5,4)	46,3 (5,9)
	Corporate spending	480,9 (62)	611,8 (78,3)	729,5 (93,4)	846,1 (108,3)	942,9 (120,7)	1019,8 (130,5)
	Foreign expenditure	8,3 (1,1)	10,5 (1,3)	8,9 (1,1)	9,4 (1,2)	9,3 (1,2)	9,5 (1,2)
	Other	5,7 (0,7)	6,8 (0,9)	9,5 (1,2)	11,2 (1,4)	11,7 (1,5)	12,6 (1,6)
R&D expenditure by source in %	Government expenditure	4,60	4,4	4,6	4,5	4,2	4,3
	Corporate spending	92,7	93	93	93,2	93,7	93,7
	Foreign expenditure	1,6	1,6	1,1	1	0,9	0,9
	Other	1,1	1	1,2	1,2	1,2	1,2

Source: own representation based on data from the Ministry of Science and Technology (MOST) 2018

In terms of sectors, the highest budget was spent on R&D in computer and ICT applications, the field of activity of Huawei and other large companies, at 16.1 % of total expenditure in 2015. Electrical machinery and manufacturing equipment (10.1 %) and automotive manufacturing (9 %) follow. (Ministry of Science and Technology (MOST) 2018) . According to a survey by the Stifterverband on R&D in industry in 2017, the focus of R&D in German industry in 2016 is different. In Germany, the focus on manufacturing is particularly on motor vehicles and motor vehicle parts with 34.8 % of total expenditure on R&D, electrical equipment and electronic and optical products are at 15.8 % and pharmaceutical products at 7.1 %. (Stifterverband 2019) . This weighting is also reflected in the assessment of German experts: Germany's strength is in engineering and China's strength is in the development of new business models, which is particularly crucial in the digital industry (Interviews, 2019).

4.3.3 Chinese National Enterprise Innovation Survey

China conducted the first industrial enterprise innovation survey in 2007 based on the OECD's Oslo Manual. The second "National Enterprise Innovation Survey" was conducted in China in 2017 by the National Bureau of Statistics (NBS) for industry, construction and services, also on this basis. According to the results of the 2017 survey, innovation activities in four forms played a role in around 40 % of the companies surveyed: product innovation, process innovation, organisational innovation and marketing innovation. (Liu et al. 2018) .

Of the 192,000 enterprises that reported innovation activities in 2016, 120,000, i.e. 62.5 %, had so-called "cooperative innovations", i.e. innovation activities together with other companies or institutions. Among the 160,000 companies that reported successful technology innovations, as many as 70.8 % reported cooperative innovation. It can be seen that cooperative innovation is now one of the important factors in the innovation activities of enterprises in China. The size of the companies plays a role: the larger the company, the more openness for innovation processes and cooperation (Liu et al. 2018) . It remains unclear in the report which forms of cooperation are meant and who cooperates with whom.

According to the responses on the age of the managers/entrepreneurs surveyed in China, there is a fairly high proportion of relatively young people, with around 44% of entrepreneurs aged under 40 and 81%

under 50. This is in line with China's comparatively young academisation. The proportion of young entrepreneurs may have an impact on the innovation activity of the companies they lead.

Innovatively active companies see a high relevance of political strategies to accompany innovative capacity - which is understandable considering the political system. For example, 55 % see rules for the protection of intellectual property as important, 54 % see rules for talent recruitment and promotion as right. A significant share of Chinese companies would like to see further plans and initiatives for government financial support in prioritised industries, or tax incentives for R&D. (Ministry of Science and Technology (MOST) 2018) .

In 2016, more than 70 % of the companies were of the opinion that the lack of qualified personnel and the company identification of the personnel are important limiting factors for continuous innovation processes (this coincides with the statements of the German industry in China (German Chamber of Commerce in China 2019) . High innovation costs, lack of technical information, lack of financial resources and uncertainty of market demand are other barriers to innovation mentioned. In many cases, as many as 20% of the respondents, there is simply no need for innovation. The risk of market dominance and the ease of imitation of innovations were generally not seen as the main obstacles to innovation (Liu et al. 2018) .

4.4 Conclusion on the performance of the innovation system

The indirect indicators of the performance of the Chinese innovation system have been showing rapid and clearly positive developments for years. Publication numbers have reached the level of the USA, and the quality of publications is also improving. Co-publications show China's very high focus on cooperation with partners in the USA. Chinese patent applications have high growth rates both in international applications and in national Chinese applications. China is an important knowledge and innovation actor worldwide, with which cooperation is imperative for a knowledge-based economy like Germany. The comparison of Germany's cooperation with China with the cooperation of other countries with China indicates that there is still potential for expanding German-Chinese cooperation.

An interesting aspect might be suggested by the input-output view that in some industrialised countries higher R&D expenditures - in contrast to the previous development - no longer lead to increasing publication numbers. The question of whether R&D systems reach a point of marginal productivity may be of interest for further research.

According to the official Chinese reports on the innovation capacity of companies, the importance of research activities in companies has increased rapidly in the last 20 years. The topics of large and relatively young digital firms play an important role. China now has an R&D structure of business, universities and research institutions in some provinces that looks similar to that in developed countries. Despite the large human resources available, the limitation of suitable personnel, along with available finances, plays a hurdle in further innovation. Chinese companies want a clear policy framework.

5. R&I system functionality in China at regional level

The aim of the chapter is to strengthen the understanding of system functionality in China. The strategic approaches and specifications described in Chapter 2 are broken down in practice to the provincial, individual city and district levels. These are responsible for the formulation of implementing regulations and local-specific rules. In relation to the technology sector, they are intended to reach individual companies and research centres or universities in order to strengthen the location of the local level and thus China as a whole.

The multiplicity, diversity, unclear formulation, temporal and thematic overlapping of plans and reports make the Chinese system quite opaque to the external, but also to the internal observer. (Yang 2019b) . In addition to the "Medium- and Long-Term Plan for S&T Development (2006-2020)" and the "13th

Five-year Plan on Science, Technology and Innovation" (see Chapter 5.1.2), according to the National Centre for S&T Evaluation (NCSTE), another 60 "Special Policies", 80 "Regulations", 62 "Tasks" and 242 "Policy Measures" on research and innovation were issued at the national level between 2006 and 2015. (Yang 2018 ; Interview 2019). Even Chinese experts have difficulty keeping an overview of how this accumulation of central plans, regulations and measures affects the research landscape and local R&D policies (Interview 2019). This is then compounded by a wide variety of local implementation regulations.

According to Tse, the resilience with which China's development model reacts to internal and external challenges and obstacles can be explained by the so-called "three-layer duality". (2016) can be explained by the so-called "three-layer duality": At the top level, the central government formulates guidelines and goals, which the rest of the administrative apparatus at regional and local level follows according to a top-down model. At the middle level are the regional and local administrative bodies, which try to channel and coordinate innovative ideas with targeted support measures and cooperation in order to achieve the ideas or milestones set by the government. (Tse 2019) .

The public and private enterprises operating at the lower level, the so-called "duality" of enterprises, as well as the research institutes are supposed to be the executing forces and the beneficiaries of the national innovation plans (Tse 2016) . In this context, science parks (see chapter 5.2) play a role as a policy instrument for economic growth by attracting in particular small and medium-sized high-tech enterprises (SMEs) (Cheng et al. 2014) . Science Parks provide these companies with services of various kinds to support them in their innovation activities (Interviews 2019). The type of services, which goes as far as financial support, varies and depends on the respective provincial or district policy and also on the respective investor of the park.

Over time, the Chinese government has realised that this purely top-down approach does not sufficiently improve innovation capacity in a way that leads to indigenous innovation. Freedom of action for local governments in the use of budgets and in the development of instruments is now helping to improve innovation-oriented plans and their implementation. (Heilmann et al. 2013, p. 905) . The openness of administration, companies and the population to new technologies favours a disruptive innovation policy. (Sieren 2019) . Successful pilot projects at the regional level thus sometimes count as drivers for a successful strategic orientation of the central government. (Heilmann and Melton 2013, p. 594) .

Regional R&D policy stands out because of another feature: financial support at the regional level exceeds (not in all provinces, but in Guangdong, for example) central government funding. This middle level of "three-layer duality" thus helps in the first place to implement national plans, but it also always pursues its own goals. The framework that the central government sets for this is "fluid" and must always be re-tared depending on the actor, role, time, province, etc. In principle, the actors at the middle level have the right to act in their own interest. Basically, the actors at the middle level have a natural interest in gaining far-reaching advantages for themselves and their region or the respective sectors through the implementation of trend-setting central guidelines (Frietsch et al. 2018a; Publications Office of the European Union 2019; Breznitz and Murphree 2011).

Some national plans and programmes have a special relevance for technological development in China because of their political importance, their budget or also their long-term nature. One such programme is the so-called Torch Programme. It is the central implementation tool for the local level to implement the central government's plans, as is done for example in the Greater Bay Area (GBA).

Due to the complexity, the analysis focuses on the implementation approaches for the GBA and Guangdong Province mentioned by the Chinese interviewees as currently relevant. Three aspects are examined in this chapter: 1) the interaction between the strategies at the national level and the implementations at the local level using the example of the Greater Bay Area and the centrally acting Guangdong Province. Two relevant levels are considered: the provincial administration and the Science Parks/High and New Technology Zones (HNTZ). The Torch Programme is also included here. 2) Two

Science Parks as concrete implementation units are presented as examples to illustrate their functioning. 3) The instruments used in Guangdong Province to drive innovation and the potential opportunities for Germany and German actors are presented.

5.1 Greater Bay Area: National Plan and Regional Implementation

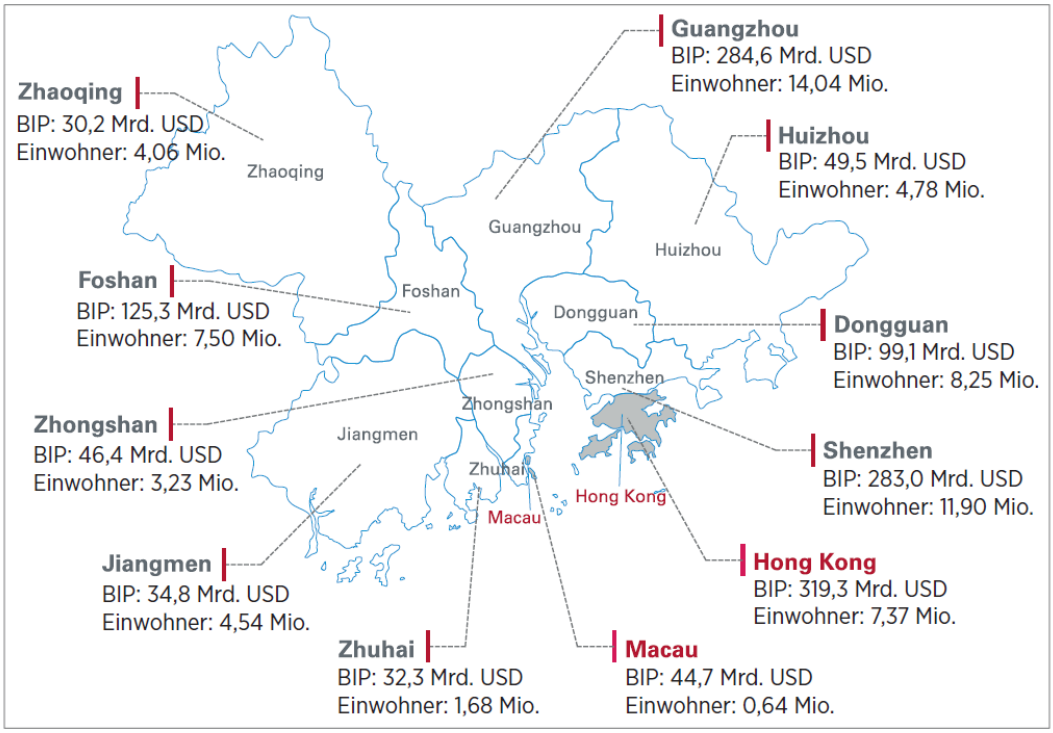
The GBA is a strategically grouped region consisting of Hong Kong, Macao and nine cities from Guangdong province. The economic, political and innovative importance of the region and the interplay of strategic approaches of the central and provincial levels are illustrated in the following chapter.

5.1.1 Greater Bay Area and Guangdong Province

The GBA is a 56,000 km2 coastal region with a population of over 66.7 million in southern China, comprising the Hong Kong Special Administrative Region (HKSAR) and Macao Special Administrative Region (Macao SAR), and the cities of Guangzhou, Shenzhen, Zhuhai, Foshan, Huizhou, Dongguan, Zhongshan, Jiangmen and Zhaoqing, all located in Guangdong Province (see figure 34) (Secretary for Constitutional and Mainland Affairs 2019, p. 1; KPMG and HKGCC 2017, pp. 6-7). .

Guangdong Province, in the wake of the Open-Door Policy (1979), has developed into China's economically strongest and most innovative province early on since the 1980s (Sigurdson 2004, p. 8) . With a gross regional product (GRP) of 9.7 trillion RMB (approx. 1.2 trillion RMB), Guangdong is the most innovative province in China. RMB (approx. EUR 1.2 billion), Guangdong is the richest province in 2018, contributing nearly 11% of China's GDP (National Bureau of Statistics of China (NBS) 2019). In 2016, Guangdong's foreign trade volume accounted for a disproportionate 25% of China's total (USD 954 billion, approx. RMB 6.7 trillion), illustrating the region's strong export focus (Gätzner 2018, p. 13).

Figure 34: Geographical, economic and demographic information on the cities of the Greater Bay Area



BIP = GDP, Einwohner = population
Source: Gätzner 2018, p. 13 ; KPMG and HKGCC 2017

A central role in the region's development is played by the city of Shenzhen, which was designated a

special economic zone in 1980 and attracted domestic and foreign companies with subsidised land and a low corporate income tax of 15% (about half the national rate) (Breznitz and Murphree 2011, p. 17) .

Special economic zones in China are geographically demarcated areas, with their own administration and a separate customs area (often duty-free), where uniform business procedures are applied and where companies located there receive certain benefits. (World Bank 2010). They are functionally more diverse and cover much larger land areas than other types of economic zones. In China, the term special economic zone (SEZ) usually refers to the following seven specific zones: Shenzhen, Zhuhai, Shantou, Xiamen, Hainan, Shanghai Pudong New Area and Tianjin Binhai New Area.

Shenzhen was originally established as a Special Economic Zone (SEZ) in 1980 to operate a socialist market economy, as it is close to Hong Kong. In the following three decades, Shenzhen received a huge influx of industrial investment, most of which was in low-tech manufacturing activities.

Numerous production facilities focusing on the final assembly of information and communication technology (ICT) products have sprung up in Shenzhen and increasingly in the surrounding cities. In order to make production more qualitative, faster and more cost-efficient, companies gradually invested in technology development and thus managed to gradually shift their focus from simple assembly and production activities with low profit margins to producing their own technology innovations (Breznitz and Murphree 2011, p. 20; Sigurdson 2004, p. 10) . This is exemplified by ZTE and Huawei, which were founded as trading companies in Shenzhen in the 1980s and are now among the world's leading telecommunications companies. (Breznitz and Murphree 2011, p. 21) . Shenzhen is also home to global market leaders such as Tencent, the developer of WeChat with a specialisation in AI, the battery and electric car manufacturer BYD and the drone manufacturer DJI, which has a global market share of 70%. (Rohde 2019b; Gätzner 2018, p. 17) .

In the past three decades, Shenzhen has developed from a fishing town with a population of 30,000 into a metropolis with over 12 million inhabitants (Gätzner 2018, p. 13) . Worldwide, only the ports of Shanghai and Singapore have a higher goods turnover than Shenzhen's, with 24 million standard containers. (Gätzner 2018, p. 13) .

A distinctive feature of the development of Shenzhen and other cities in Guangdong is that the industry is dominated by private companies and is thus somewhat more detached from national programmes and government influence. The disadvantages that this industry has faced due to the lack of government support have been turned to its advantage by the low level of political influence:

- The production of ICT hardware is dependent on the import of high-quality components and generates a low profit margin. It also results in high energy consumption and environmental pollution. For this reason, this industry originally received little support from the Chinese government. (Breznitz and Murphree 2011, p. 16) . In Guangdong, private enterprises overrode this and a nationally unique ICT agglomeration developed, accounting for 76.8% of all Chinese electronics and ICT exports in 2009. (Breznitz and Murphree 2011, p. 17) . Due to the differentiation of enterprises over the past four decades, almost the entire production process from development to the manufacture of individual components to final assembly can be implemented in the region. Up to 90 % of the components for ICT hardware are sourced from Guangdong itself, so that the dependence on imports has decreased and a higher value added is achieved. (Breznitz and Murphree 2011, p. 23) .
- When it comes to granting loans, large companies and state-owned enterprises are favoured over smaller and private SMEs. Contributing to the flourishing of private enterprises in Guangdong, in addition to tax breaks and subsidies from the local and provincial governments, is an informal rotating financing system in which enterprises lend to each other on a trust basis. For example, a manufacturer can buy components from a supplier on credit and pay for them once the final product has been sold to the customer (Breznitz and Murphree 2011, pp. 24-26) . Since

companies in Guangdong are in a strong relationship of dependency, they mostly abide by the agreements, so this system, according to Breznitz and Murphree (2011, S. 26) works reliably.

- In response to weak IP protection in China, companies in Guangdong released new innovations incrementally and quickly. This meant that new models were brought to market at short intervals in order to continuously counteract product piracy. (Breznitz and Murphree 2011, p. 19) . Private companies therefore invest on average significantly more in R&D than state-owned enterprises and are characterised by being particularly application- and market-oriented. (Gätzner 2018, p. 18) .

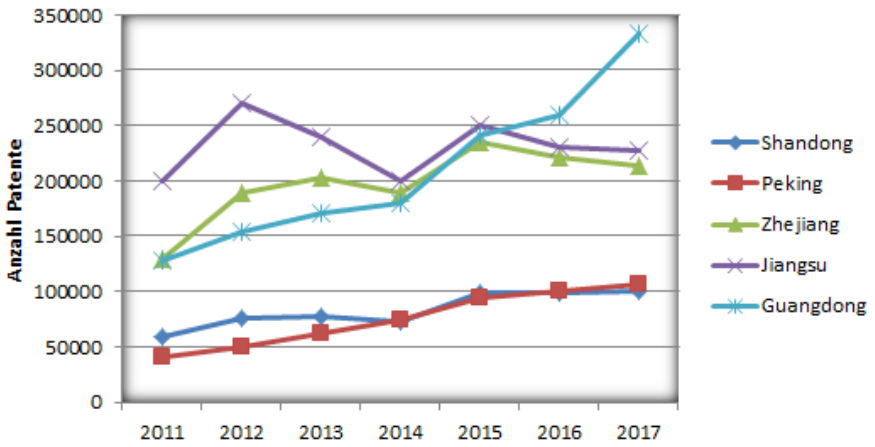
Guangdong's growing importance as a technology and innovation hub is reflected, among other things, in the number of High and New Technology Development Zones (HNTZs) (see Chapter 5.2): Guangdong is home to 12 HNTZs, making it the province with the most HNTZs. The more than 97,000 registered enterprises in the HNTZs employ over 2.3 million people across China and generate 3.1 trillion RMB (approx. 380 billion RMB). RMB (approx. 380 billion EUR) in operating revenue (as of the end of 2017). (Torch High Technology Industry Development Center, Ministry of Science & Technology (科技部火炬高技术产业开发中心) 2018, p. 4) .

Investment in R&D in Guangdong amounted to RMB 200 billion (approx. EUR 25 billion) in 2016 and the share of spending on R&D as a percentage of GDP was 3% in the GBA and 4% in the city of Shenzhen. This puts the region above the investment of other provinces and the nationwide spending share of 2%. (Gätzner 2018, p. 17) .

Since 2016, Guangdong has been the province where most domestic patents are granted (see Figure 35). In 2017, over 330,000 new patents were filed in Guangdong (State Intellectual Property Office of the People's Republic of China (SIPO) 2018, p. 97) . More than 90% of R&D activities in Guangdong take place in private companies, which (Sigurdson 2004, p. 9) which means that they hold a large number of patents. Two of the top five companies worldwide with the most patent applications in 2018 are located in Shenzhen: Huawei ranks first with 5,405 and ZTE fifth with 2,080. Universities in Guangdong also fare well in the global comparison of patent applications. Shenzhen University (founded in 1983) ranks [6] third in the world with 201 patent applications and South China University of Technology in Guangzhou ranks fourth with 170 patent applications. (Wang 2019) . The R&D activities of companies in Guangdong are particularly specialised in IT, high-end manufacturing, biomedicine, new materials and renewable energy. Efforts are being made to expand research in the fields of robotics, drones and big data. (Gätzner 2018, p. 17) . The representation of patent applications over time shows the importance of the province for China and the rapidly growing importance of tech companies in the province.

[6] In second to fourth place are Mitsubishi Electric (2,812 patents), Intel (2,499 patents) and Qualcomm (2,404 patents).

Figure 35: Number of domestically granted patents in China's five most patent-rich provinces (2011-2017)



Source: (State Intellectual Property Office of the People's Republic of China (SIPO) 2018) , S. 97-98

In order to follow the national strategies and use them for its own region, the Guangdong provincial government drafts its own plans. Currently, the five-year plan of Guangdong Province, the document No. 1 with 12 regulations on innovation policy of 2017 and the guidelines on the construction of laboratories at the provincial level are relevant (Department of Science and Technology, Guangdong Province (广东省科学技术厅) et al. 2015) . The importance of the Science Parks and the High and New Technology Development Zones (HNTZ) is particularly emphasised (see chapter 5.2). Guangdong is already the province with the most HNTZs and aims to build up to 15 HNTZs in the "National HNTZ" category and 30 HNTZs (and more) in the "Provincial HNTZ" category by 2020. (Ye Qing（叶青) 2017) . The plans for regional expansion of HNTZs give indications that there will be huge demand in the near future in areas such as infrastructure, construction, real estate, financial services, innovation and technology. The simultaneous opening up of the Chinese economy provides an opportunity for foreign companies to establish branches in the GBA and gain a foothold in the Chinese market (KPMG 2019) .

5.1.2 National plan and regional implementation

As explained in Chapter 2, the system functionality of research and innovation in China, like all other areas, is determined by forward-looking policies such as various initiatives and plans respectively for the future. These directional policies do not represent a concrete strategy with an underlying operational process (Interviews 2019). They can therefore also change over time, or be partially or completely supplemented, replaced or overlaid by other documents.

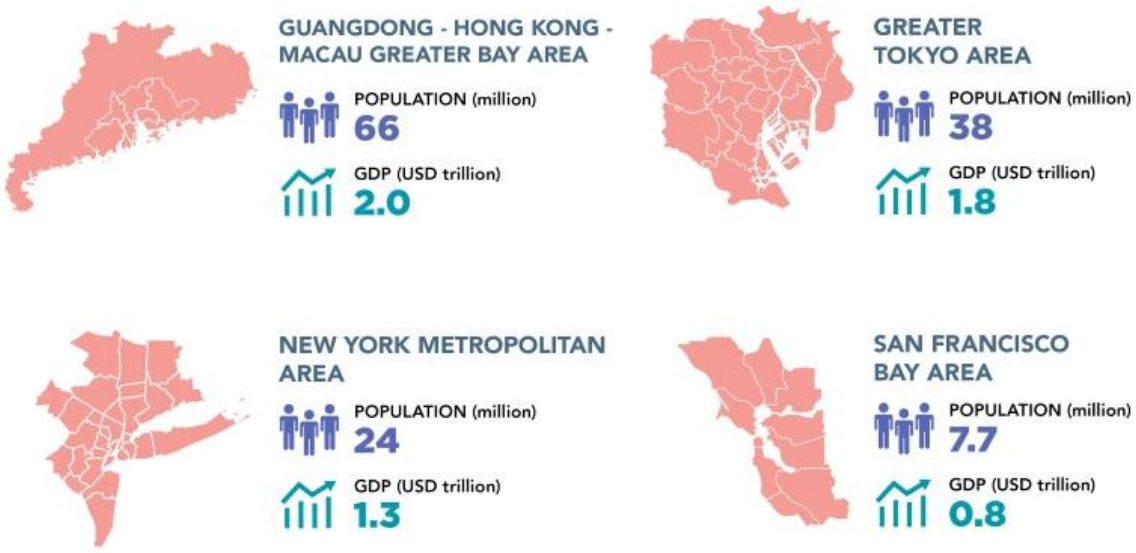
The initiative on the GBA was launched by the central government in February 2019. (Secretary for Constitutional and Mainland Affairs 2019; 《粤港澳大湾区发展规划纲要》（双语全文）(Outline of the Guangdong-Hong Kong- Macao Greater Bay Area Development Plan) 2019) enacted. The GBA was first mentioned in the 13th Five-Year Plan in 2016. Previously, the cities in Guangdong were referred to as the Pearl River Delta (PRD) and their development was promoted separately from Hong Kong and Macau.

Due to the geographical proximity to Hong Kong and Macao and the economic importance of the entire region, plans for the PRD or GBA have been advanced for a good ten years with the aim of turning southern China into an innovation centre for the entire country (Interview 2019). Through the GBA plan, Hong Kong and Macau will now also be more integrated into the plans and the environment of Mainland China. This is also part of the integration of the two Special Administrative Regions under the "One Country, Two Systems" agreement. Furthermore, the JCC is expected to serve as a catalyst for the

BRI (KPMG and HKGCC 2017, p. 7) . The GBA is to be transformed into a world-class innovation centre or cluster, similar to Silicon Valley or Tokyo. (Secretary for Constitutional and Mainland Affairs 2019) .

According to Rohde (2019a, p. 15) the choice of the name GBA implies that China is aiming to compete with the Greater Tokyo Area in Japan and the San Francisco Bay Area (Silicon Valley) in the USA. Although the GDP of the GBA is higher than that of comparable high-tech zones in absolute terms, in terms of economic output per capita the region lags behind (see Figure 36). (Gätzner 2018, p. 16) .

Figure 36: The largest book regions worldwide



Source: Pharma Boardroom 2018, p. 7

The GBA Outline Development Plan will be highly relevant for the innovation landscape in the GBA and especially in the economically most important Guangdong province. However, the impact of the plan cannot yet be assessed due to its recent publication (interview 2019). However, there are predecessor plans and other overlapping documents that have already influenced structures and instruments in the GBA area, including in Guangdong Province (see Figure 37).

The Road to the Outline Development Plan for the Greater Bay Area

The GBA (or PRD) is increasingly addressed in national planning documents. As described, the central plans are taken up by the local government and translated into more concrete guiding documents and economic instruments according to local conditions and interests, as is the case in Guangdong (Interview 2019). Strategic documents for the development of the region are presented below:

- 2008: The Outline of the Plan for the Reform and Development of the Pearl River Delta (2008-2020) (《珠江三角洲地区改革发展规划纲要(2008-2020 年)》)

  The overall planning and strategic approach to the Greater Bay Area builds on the 2008 Outline of the Plan for the Reform and Development of the Pearl River Delta (PRD Outline). The document contains goals and measures for the economic and social development of the region. It aims to build a modern industrial system with a focus on modern services, advanced manufacturing and cutting-edge technologies. Further goals are the modernisation of the regional infrastructure and environmental protection through effective land use, the development of a circular economy and the reduction of air pollution. Although the document mainly refers to the province of Guangdong, it already aims at supra-regional cooperation with Hong Kong, Macao and Taiwan as well as the ASEAN states. (National Development and

Reform Commission (国家发展和改革委员会) 2008) .

- 2010: Framework Agreement on Hong Kong/Guangdong Cooperation (Framework Agreement) (《粤港合作框架协议》)

  The supplementary agreements and plans of 2010 and 2011 are interesting in that they translate the already generally formulated goals in the PRD Outline into concrete measures. The document defines environmental protection and preservation of ecology as central goals of the cooperation between Hong Kong and Guangdong. The quality of life in the region is to be improved by combating air pollution, improving clean production, promoting the widespread use of electric vehicles, protecting seawater quality, developing a circular economy and preserving marine resources. (Hong Kong and Macao Affairs Bureau of the People's Government of Guangdong Province (广东省人民政府港澳事务办公室) 2016) .

- 2011: The National Twelfth Five-year Plan (2011-2015) (《国家第十二个五年规划》)

  The 12th Five-Year Plan is outstanding because it formulates China's planned economy/five-year plans for Hong Kong and Macao as well for the first time. This not only underlines the gradual rapprochement of the Special Administrative Regions with the mainland, but also shows the already achieved integration of both territories into China's industrial and innovation policy. Especially with regard to Hong Kong, the special importance of certain sectors, such as international finance, becomes clear. By focusing on and strengthening new emerging industries in the GBA, the Hong Kong Special Administrative Region is expected to enter into a symbiotic state with Guangdong to produce a world-class cluster. (Central People's Government (中华人民共和国中央人民政府) 2011) .

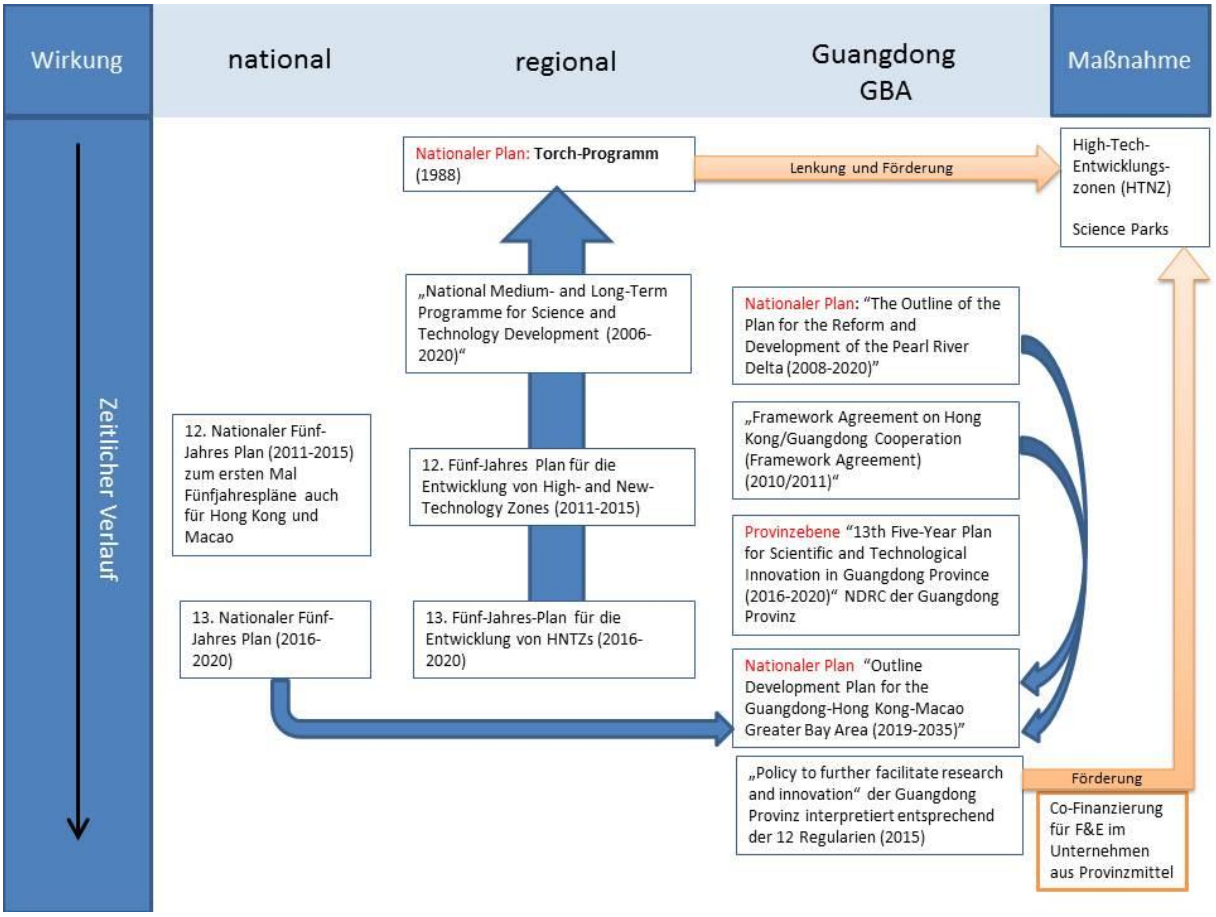
- 2016: The National Thirteenth Five-year Plan (2016-2020) (《中华人民共和国国民经济和社会发展 第十三个五年规划》)

  The 13th Five-Year Plan sets as a goal the promotion of the PRD as one of three world-class city clusters (along with Beijing-Tianjin-Hebei and Yangtze River Delta). The opening up, transformation and upgrading of the PRD will be accelerated by opening new science and technology centres and industrial innovation centres in Shenzhen. The development of the Guangdong-Hong Kong-Macao Greater Bay Area will be reinforced for the first time in a national plan (National Development and Reform Commission (NDRC) 2016, 94, 106, 153) . The concept of the GBA is based on a document jointly issued by Hong Kong, Macao, the cities of Shenzhen, Dongguan, Guangzhou, Zhuhai and Zhongshan in 2011, "The Action Plan for the Bay Area of the Pearl River Estuary". (KPMG and HKGCC 2017, p. 7) .

- 2019: Outline Development Plan for the Guangdong-Hong Kong-Macao Greater Bay Area (2019-2035) (《粤港澳大湾区发展规划纲要》)

  The development plan for the GBA envisages building a dynamic world-class city cluster and global technology and innovation hub through the development of new National Innovation Demonstration Zones (NIDZ, see Chapter 5.2). (Secretary for Constitutional and Mainland Affairs 2019, p. 15) . The GBA, as a coastal region, is expected to contribute to the implementation of the maritime BRI and strengthen the connection between Hong Kong and Macau with mainland China through development zones in Qianhai, Nansha and Hengqin. (KPMG 2019, P. 1) . To implement the goals, the expertise and strengths of each city will be combined. Shenzhen and Dongguan are the centre for business, innovation and advanced electronics manufacturing, Zhuhai and Foshan for advanced equipment manufacturing, Hong Kong for finance, transport and logistics, and Macao for cooperation with Portuguese-speaking countries and tourism. (KPMG 2019, P. 2-3) .

Figure 37: Interrelationships of national and regional planning in the Greater Bay Area



Source: own representation

5.2 High-tech zones and science parks

In 1984, the central authorities created a variant of the above-mentioned special economic zones (SEZs), the economic and technology development zones (ETDZs). ETDZs are usually located in the suburban regions of a major city. Within the ETDZ, a management committee, usually selected by the local government, oversees the economic and social management of the zone on behalf of the local government (China Special Report: Industrial Parks-China's Vehicles for Manufacturing. 2009) . Within these zones, different rules and regulations apply than in the rest of the country in order to be attractive to domestic and foreign investors. The infrastructure is also better developed. These SEZs and ETDZs also serve the Chinese government as a "testing ground" for regulation and economic management. (Webber et al. 2002) .

The Torch Programme was initiated at the end of the 1980s. In addition to the ETDZs, High- and New-Technology Zones (HNTZs) are also established as a result, which are aimed more strongly at technology development. These zones are also referred to as science parks in the literature. (van Essen 2007) .

In addition to nationally recognised HNTZs, there are also provincial HNTZs.

In addition to the relatively fixed and recognised HNTZs and also ETDZs, various other forms of local technology agglomerations exist in China under the term "science parks". The most recent development is National Innovation Demonstration Zones (NIDZ), which have been introduced since 2009.

During three decades of steady economic growth and technological development with strong govern-

ment support at all levels, national SEZs, ETDZs, national and provincial HNTZs and other varieties of science parks played a central role in China's science, technology and innovation agenda.

5.2.1 Torch Programme and the importance of High-Technology Development Zones

The Torch Programme (*huoju jihua/guihua* 火炬计划/规划) plays a prominent role in China's central-local innovation policy. It was launched in 1988 by the State Commission for Science and Technology (now: Ministry of Science and Technology (MOST)) and formulated as a specific goal the commercialisation, industrialisation and internationalisation of domestic R&D. (DEVELOPMENT Solutions Europe Ltd. 2017, p. 6; Heilmann et al. 2013, p. 901) . The programme contains three core objectives: 1) the establishment of new High and New Technology Development Zones (HNTZs, also known as High-Tech Zones (HTZs) or Science Parks), 2) the design of service centres that have the support of HNTZs as their main purpose, and 3) the promotion of projects and companies that are considered promising in the fields of new materials, biotech and electronics. (Sigurdson 2004, p. 7) . Tasks of the Torch High Technology Industry Development Center, for example, are to enforce tax, investment and trade policies favourable to HNTZs and to support researchers and entrepreneurs in business management and product marketing (Heilmann et al. 2013, pp. 906-907). Since 1999, Torch has also awarded innovation funds to private SMEs with a technological focus in the HNTZs: through loans, subsidies, investments and seed capital for start-ups, an assortment of support is offered (Heilmann et al. 2013) .

High and New Technology Development Zones (HNTZ)

The central government must formally recognise all HNTZs under the Torch programme. According to Heilmann et al. (2013, S. 907) the requirements for recognition of HNTZs are indicative, requiring them to meet minimal quantitative targets. As a result, HNTZs sometimes differ greatly in their organisational structure, incentive policies and the level of qualification of the companies and people located there. (Heilmann et al. 2013, p. 907) . Guangdong hosts a total of 12 HNTZs (as of end-2017). (Torch High Technology Industry Development Center, Ministry of Science & Technology (科技部火炬高技术产业开发中心) 2018, p. 4) .

Unlike much of the national innovation plans, the Torch programme is not aimed at state-owned companies or research institutes, but primarily at private companies and individual researchers and research groups (Heilmann et al. 2013, p. 906) . In economic terms, HNTZs are hubs in their own right, which differ from the rest of the country in terms of their innovation-economy design and orientation. On the one hand, their goal is to promote high-tech industries. On the other hand, HNTZs are often experimental fields whose results are used in the further development of national and regional programmes. (DEVELOPMENT Solutions Europe Ltd. 2017, p. 6, 48) . HNTZs also function as catalysts for technological innovations and are an indispensable part of the national innovation system. (DEVELOPMENT Solutions Europe Ltd. 2017) .

Indeed, of the 103,631 HNTZ enterprises nationwide, only 4,430 are large enterprises and the remaining 95.73% are medium, small or micro enterprises (Torch High Technology Industry Development Center, Ministry of Science & Technology（科技部火炬高技术产业开发中） 2018, p. 28) . Of all the registered high-tech enterprises (48,917 in total) in the HNTZs, only 2.29% are state-owned enterprises. Large parts of the remaining enterprises are private (42.74%), limited liability companies (34.12%) and joint stock companies (12.17%). (Torch High Technology Industry Development Center, Ministry of Science & Technology（科技部火炬高技术产业开发中心）2018, p. 26) .

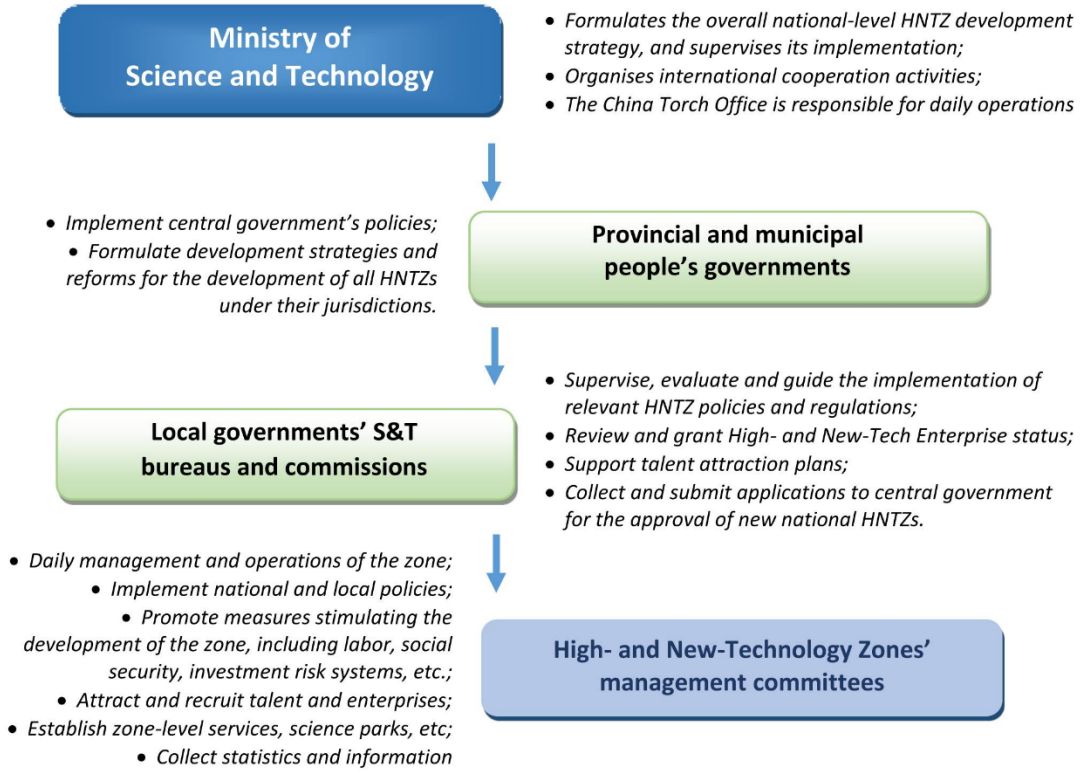
The overall objectives of the Torch Programme are set at the national level by the government. In January 2013, the government published the 12th Five-Year Plan for the Development of High- and New-Technology Zones, a document dedicated exclusively to HNTZs. The goals set out in the document include attracting 3,000 international talents and developing HNTZs with international competitiveness. In the "Notice on Issuing the HNTZs' Innovation-driven Strategy Upgrading Action and Implementation

Plan", MOST issued the main document on the strategic development of HNTZs until 2020 in March 2013 and specified the targets (DEVELOPMENT Solutions Europe Ltd. 2017, p. 7) .

The goals formulated in the following 13th Five-Year Plan for the Development of HNTZs (2016-2020) (published: May 2017) with regard to HNTZs are much more ambitious: the number of HNTZs is to be increased to 240 HNTZs by 2020 and an annual registration rate of new companies of 15 % is to be achieved. The HNTZs are to participate with a share of up to 6.5 % in public and private expenditure on R&D activities and experiments. Furthermore, the plan formulates the establishment of an innovation network, the increase of the total value of the HNTZ service sector to 25 % of GDP and more involvement of HNTZ companies in the BRI as goals. (DEVELOPMENT Solutions Europe Ltd. 2017, p. 9).

Figure 38: Hierarchy levels for the Torch programme and the HNTZ

Division of responsibilities among central and local administrations for the management of HNTZs



Source: DEVELOPMENT Solutions Europe Ltd. 2017, p. 7

The Torch programme is a classic top-down approach with central coordination at national level and central support institutions. At the same time, the HNTZs supported by the Torch Programme are purely local and decentralised initiatives, as implementation and funding is under the control of the municipalities and HNTZs themselves (Heilmann et al. 2013, p. 906-907) . This establishment is highly dependent on local economic conditions. Among other things, local governments set regulations regarding tax relief, land and space use, and conditions for grants and subsidies. (DEVELOPMENT Solutions Europe Ltd. 2017, p. 18) . All initiatives under the Torch programme, including the HNTZs, are 65% business-funded and only 1% government-funded. This clearly distinguishes the programme from other national technology programmes such as the 973 and 863 programmes (see Table 9).

Table 9: Funding sources of selected Chinese national technology programmes

	973 programme	863 programme	Torch programme

Government	96 %	39 %	1 %
Company	k. A.	k. A.	65 %
Bank loan	k. A.	k. A.	22 %

Source: Heilmann et al. 2013, p. 902

As described above, the experiences from the HNTZs are taken into account in the formulation of national technology strategies. An example is the 530 Plan of[7]the HNTZ Wuxi, which served as a template for the 1000 Talents Programme at the national level (Heilmann et al. 2013, pp. 908-909) .

For the exchange of Torch HNTZs on a horizontal level, several platforms have been created such as the Association of Chinese HNTZs (founded in 1992), the National HTZ Work Conference (annual meetings in Beijing, founded by MOST in 1991) and the Joint Conference of HNTZ Directors (annual meetings at different locations, founded in 2002). (Heilmann et al. 2013, p. 906).

The first HNTZ was created with the Beijing New Technology Industry Development Zone (Zhongguancun). Between 1991 and 1992, another 51 HNTZs were established (DEVELOPMENT Solutions Europe Ltd. 2017, p. 6) . By 2010, the number was below 60 HNTZs, but since then many more zones have been established, so that in 2017 there are 156 HNTZs under the Torch programme (as of 2017)(Torch High Technology Industry Development Center, Ministry of Science & Technology (科技部火炬高技术产业开发中心) 2018, p. 4) . In March 2018, the establishment of twelve more HNTZs was announced. (China Briefing 2018) . With 67 HNTZs, a disproportionately high number are located in eastern regions of China (see Figure 39). (Torch High Technology Industry Development Center, Ministry of Science & Technology (科技部火炬高技术产业开发中心) 2018, p. 4) . The National Medium- and Long-Term Programme for Science and Technology Development (2006-2020) has contributed to the surge in HNTZ numbers from 2010 onwards. Aiming to raise China to the level of an innovation nation by 2020, the programme envisages the creation and strengthening of HNTZs as incubators for R&D and high-tech industries (DEVELOPMENT Solutions Europe Ltd. 2017, p. 6) .

Figure 39: Number of high tech zones per province

[7] With the 530 Plan, Wuxi aimed to recruit 30 top Chinese researchers living abroad in five years through financial incentives such as high incomes and free office and residential space.

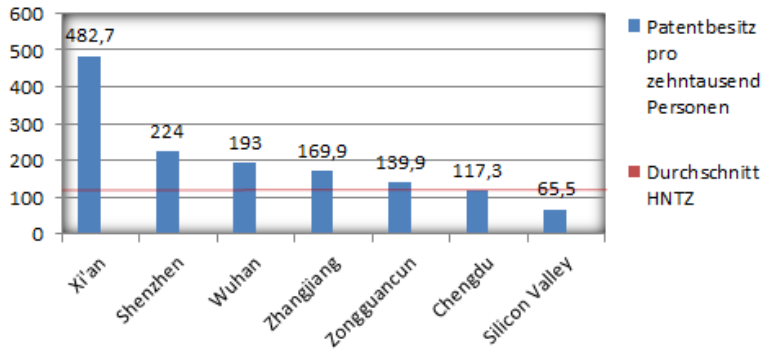
Source: DEVELOPMENT Solutions Europe Ltd. 2017, p. 8

HNTZs make a high contribution to the export growth of higher-value technological products. (Heilmann et al. 2013, p. 897; DEVELOPMENT Solutions Europe Ltd. 2017) . For example, the share of HNTZ exports as a percentage of all Chinese exports increased from 2% in 1995 to 16.7% (2009) to 21.12% (2017) (Heilmann et al. 2013, p. 897; Torch High Technology Industry Development Center, Ministry of Science & Technology (科技部火炬高技术产业开发中心) 2018, p. 3) . HNTZs account for more than 30 % of total R&D expenditure (Heilmann et al. 2013, p. 897) .

Of the 19.4 million employees in HNTZs, over 56% have at least a college degree. (Torch High Technology Industry Development Center, Ministry of Science & Technology (科技部火炬高技术产业开发中心) 2018, p. 27) . The HNTZs attract only limited capital and skilled personnel from abroad: just under 6.7% of all companies and 4.5% of hi-tech companies are financed from abroad. (Torch High Technology Industry Development Center, Ministry of Science & Technology (科技部火炬高技术产业开发中心) 2018, p. 26) . In 2017, HNTZs had a total of 62,561 foreign employees and 126,029 Chinese scholars returning from abroad, accounting for only 0.32% and 0.65% of all employees, respectively (Torch High Technology Industry Development Center, Ministry of Science & Technology (科技部火炬高技术产业开发中心) 2018, p. 27).

New patent applications by companies in HNTZs accounted for about 187,000 in 2015, 17 % of all patent applications by companies in China. On average, there are 164.8 patents per 10,000 people in HNTZs, which is higher than Silicon Valley's average of 65.5 (see Figure 40) (DEVELOPMENT Solutions Europe Ltd. 2017, p. 15-16) .

Figure 40: Average patent applications per ten thousand people in HNTZ (2015)



Patenbesitz pro zehntausend Personen = patents ownership per ten thousands individuals, Durchschnitt HNTZ: HNTZs' average
Source: DEVELOPMENT Solutions Europe Ltd. 2017, p. 16

DEVELOPMENT Solutions Europe Ltd. (2017, S. 3–4) recommends in an ad hoc study commissioned by the EU Commission on financial incentives for innovation in China that European companies locate in Chinese HNTZs. This offers the advantage of being able to enjoy tax incentives and preferential policies and of being embedded in an innovation-rich landscape. In addition, the HNTZ administration supports foreign employees in applying for visas and finding accommodation, thus facilitating the establishment process in China. (DEVELOPMENT Solutions Europe Ltd. 2017, p. 18) . It is necessary for foreign companies to select the HNTZ according to their needs and to have the process of establishment accompanied by experts in legal, tax and governmental affairs. (DEVELOPMENT Solutions Europe Ltd. 2017, p. 3-4) .

High- and New Technology Enterprises (HNTE)

The Chinese central government has been promoting R&D actors through the designation of High and

New Technology Enterprise (HNTE) under the Corporate Income Tax Law since the 1990s. Originally, HNTEs were located exclusively within HNTZs, but since 1996 recognition has also been open to enterprises outside the zones (DEVELOPMENT Solutions Europe Ltd. 2017, pp. 11-12) . However, they still account for almost half of all high-tech enterprises in the country. (Heilmann et al. 2013, p. 897) .

Through an "Administrative Measure for the Recognition of High and New Technology Enterprises" (MOST; MOST; SAT 29 JAN 2016) by the Ministry of Finance, the State Administration of Taxation and MOST, the incentives and recognition requirements for HNTE 2016 have been simplified. However, it is still a complex application process (Murphy and Yu 2019) .

HNTEs are subject to a reduced corporate income tax (CIT) rate of 15% instead of the regular 25%. (Dezan Shira & Associates 2017) . Other benefits of being an HNTE include:

- 150 % tax deduction from eligible R&D expenditure for CIT purposes;
- CIT exemption on profits from technology transfers, or the granting of intellectual property rights, if an HNTE achieves an annual profit of less than RMB 5 million (approx. EUR 625,000);
- Reimbursement of training costs for staff;
- Accelerated depreciation for qualifying fixed assets, worker housing assistance, land use priority, etc. (Wang 2017; Dezan Shira & Associates 2017) .

Companies that have been registered as a company in the PRC for at least one year, derive at least 60 % of their revenue from high-tech activities, have at least 60 % of their R&D expenditure in China, and have at least 10 % of their workforce made up of technical personnel performing R&D are eligible to apply for HNTE status. Furthermore, applicants must own intellectual property rights for their main products and/or services and be able to demonstrate R&D expenditure in the last three financial years that is above 5% for a total turnover of less than RMB 50 million, or above 4% for a total turnover between RMB 50 and 200 million, or above 3% for a total turnover of more than RMB 200 million. (Murphy and Yu 2019) . Preference will be given to companies that are designated as HNTEs and that cover a government-supported technology area, including in particular the following: Electronic Information Technologies, Biological and Medical Technologies, Aerospace Technologies, New Materials Technologies, High-Tech Services, New Energy and Energy Saving Technologies, Resources and Environmental Technologies, and Innovation for High and New Technologies in Traditional Industries. (Wang 2017; DEVELOPMENT Solutions Europe Ltd. 2019b; Ministry of Commerce (中华人民共和国商务部) 2008) .

HNTEs are a national status under the Torch programme, but the application and recognition process is at provincial level (DEVELOPMENT Solutions Europe Ltd. 2019b) . Only in the first step, companies are screened through a national platform (HNTE Certification Management Platform (www.innocom.gov.cn/)) based on self-assessment. The rest of the recognition process is managed by provincial authorities. In Guangdong, for example, companies can apply for HNTE status every year between March and June via an online portal of the Guangdong Provincial Department of Science and Technology (gdstc.gd.gov.cn/tzgg/). (DEVELOPMENT Solutions Europe Ltd. 2019a) . HNTE status is awarded for three years and can be reapplied for (DEVELOPMENT Solutions Europe Ltd. 2019b) .

As part of the application process, companies must submit a variety of documents. In addition to the application form, these include proof of legal establishment (registration document), intellectual property certificates, technical specifications and quality inspection reports on the product/service, a statement on employees and technical staff, and financial statements. (Murphy and Yu 2019) .

Recognition as an HNTE is open to foreign R&D companies based in China. However, of the more than 10,000 companies that are awarded HNTE in China each year, only about 3% are currently foreign companies, a large proportion of which are in turn from Hong Kong or Taiwan (DEVELOPMENT

Solutions Europe Ltd. 2019a) . Apart from that, most foreign HNTEs are from Germany or the USA. In Shanghai, for example, TÜV Rheinland, BASF New Materials, Siemens Healthineers and Loesche are registered as HNTEs. (DEVELOPMENT Solutions Europe Ltd. 2019b) .

National Innovation Demonstration Zone (NIDZ)

The Chinese government has been appointing "National Innovation Demonstration Zones" (NIDZ) since 2009 to test national plans for their effectiveness for the whole country in selected areas. The foundation for NIDZs was laid by the State Council against the backdrop of the global financial crisis in the government document "Opinions on Leveraging Science and Technology Support to Promote Steady and Rapid Economic Development". (DEVELOPMENT Solutions Europe Ltd. 2017, p. 10) .

NIDZs are established in particularly successful HNTZs, or clusters of HNTZs. Zhongguancun in Beijing (March 2009), Wuhan Donghu (East Lake) in Hubei (December 2009) and Shanghai Zhangjiang (March 2011) were appointed as the first NIDZs (DEVELOPMENT Solutions Europe Ltd. 2017, 10-11; 54) . Since then, a total of 19 NIDZs have been established nationwide, including an eight-HNTZ NIDZ in the GBA (Guangzhou, Zhuhai, Foshan, Huizhou Zhongkai, Dongguan, Zhongshan, Jiangmen and Zhaoqing) (as of February 2018). (Hu Yongqi 2018) . In doing so, the government is using instruments that are also intended to have an impact in other parts of the country as innovation-oriented measures. Accordingly, innovation-oriented tax and financial reforms for the high-tech industry are formulated and adopted and tested in the NIDZs. If these prove to be promising and efficient, they are implemented at the regional level and extended to the national level as an idea that has already been successfully applied. National strategies thus function at the local and regional level and vice versa (top-down as well as bottom-up principle). (Heilmann et al. 2013, 897, 901) .

5.2.2 Science Parks

Definition of Science Parks

Silicon Valley is considered a pioneer in the development of science parks around the world. Originally known as Stanford University Science Park, Silicon Valley emerged since the early 1950s. It was followed by Sophia Antipolis (France) in Europe in the 1960s and Tsukuba Science City (Japan) in Asia in the early 1970s. This trio represents the oldest and most famous science parks in the world. According to UNESCO, there are now over 400 science parks worldwide, and the number continues to grow. At the top of the list of countries with the most science parks is the USA, which reportedly has over 150 science parks. Japan follows with 111 science parks. China began developing science parks in the mid-1980s and now has around 100, 52 of which have been approved by the national government and the rest by local governments. (UNESCO 2019a, 2019a; Nurutdinova 2012) .

Firms located in science parks tend to be more involved in collaborations with universities and research institutions than firms outside them (Löfsten and Lindelöf 2005) . Proximity to a science park improves the possibility for students and university researchers to start a business that would most likely not have been initiated otherwise. (Monck et al. 1988) . Other goals that the founders of science parks have are, for example, the technology transfer from universities to companies or the support of start-ups and university spin-offs. (Westhead and Batstone 1998) .

Siegel et al. argues that the presence of full-time managers is an important resource for inexperienced entrepreneurs. They typically have the role of facilitating both informal and formal linkages between government agencies, universities and businesses (Siegel et al. 2003) .

Science Parks in China

In China, science parks and business incubators are primarily real estate-based organisations and are often built by real estate developers. They have identifiable administrative centres that focus on accelerating business processes through knowledge agglomeration and resource sharing. In addition to

high-tech infrastructures, science parks offer service components such as financial services. As a result, science parks offer new business opportunities even for established companies, they promote entrepreneurship and create knowledge-based jobs. (World Bank 2010) .

In China, the concepts of hi-tech zones and science parks cannot be sharply separated. According to Webber et al. (2002), the concepts of special zones, HNTZs and science and industrial parks are blurred within China and often it is a large open economic space consisting of several intertwined sub-zones (Webber et al. 2002) .

In a study, Tan (2006) compares science parks with industrial clusters in China. An industrial cluster is generally defined as a geographical concentration of firms in a particular industry with links to related institutions such as financial service providers, educational institutions and government bodies at different levels (World Bank 2009) . Although clusters come in different forms, all clusters have one thing in common: they include companies of different sizes belonging to one industry. Industry clusters are seen as a source of strategic competitive advantage and provide similar incentives to attract companies as science parks do. (Tan 2006) . While SEZs and also HNTZs are usually created through a "top-down" approach of government policy, most clusters are formed organically through a "bottom-up" process. However, some clusters have also emerged over time from or within industrial parks or even ETDZs (Zeng 2012).

Science parks, from the perspective of central and local government, are intended to improve economic growth by attracting small and medium-sized high-tech enterprises (Cheng et al. 2014) . As with HTNZs, science parks are also intended to facilitate indigenous technology development and transfer (Wang and Meng 2003) .

The results of the study by Weng et al. (2019) show that five factors are responsible for the success of a science park: Resource allocation to the park, park size, supply and funding and financial services, legal policy services and administrative capacity, and a high level of infrastructure in the park. (Weng et al. 2019) .

The management structure of the science parks helps to secure some of the success factors. The management usually consists of a so-called park management committee sent by the respective municipality and a state-owned company that is supposed to manage the parks according to the market principle. The park management committee is part of the city government and thus the park easily gets support from the local government. Legal services are also guaranteed due to the proximity to the local government (Interview 2019). According to the interviews, the committee is perceived as more important than the management: *"The resources are the most important success factors, which are only accessible to the senior managers in the management committee"* (Interview 2019).

Guangdong is the economically strongest province in the People's Republic. Parks in this region are characterised by the fact that they have often developed more positively than other parks in China (Interview 2019).

Case study Tian An Cyber Park in Shenzhen

Shenzhen is one of the most important and dynamic high-tech cities in China. In the wake of Shenzhen's post-1980 developments described above, central and local governments recognised the urgent need to promote technological upgrading and sustainable economic growth in the city. One important strategy was to build science parks to promote high-tech clusters. The first science park in China, the "Shenzhen Science Park" (Shenzhen Keji Yuan), now known as Shenzhen High-Tech Industrial Park (SHIP), was established in 1985 followed by an increasing number of other high-tech parks. In 2007, there were 52 parks in Shenzhen (Beijing Zhongguancun Software Park Development Co., Ltd (北京中关村软件园发展有限责任公司) 2018) ; (Liu Jiuru（刘九如) and Xiong Wei(熊伟) et al. 2015) .

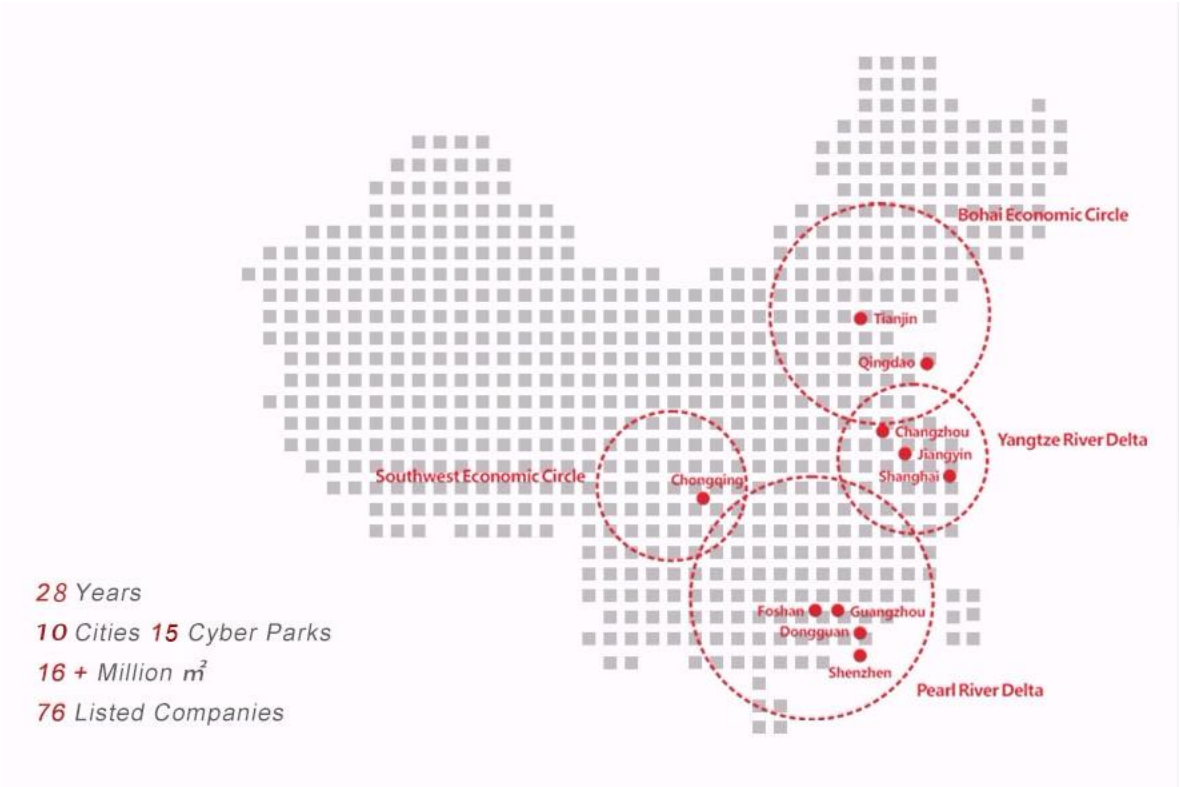
Science Parks headquartered in Shenzhen include Tian An Cyber Park, founded in 1990. The park operator is the Tian An Cyber Park Group, which manages 15 industrial properties in ten cities across China and plays an important role in industrial park development and business incubation. Currently, the group operates more than 16 million sq km of land in four national incubators. The Tian An Cyber Park in Shenzhen is home to around 12,000 small and medium-sized growth-oriented private enterprises, 80 listed companies and 100 other non-listed larger companies. In addition, Tian An Cyber Park entered into partnerships with over 100 enterprises and renowned business organisations and service organisations. The park is dedicated to building an innovative business ecosystem that provides space as well as support facilities to meet the needs of upstream and downstream enterprises at various stages of growth and to map the entire value chain of relevant industries. In addition, services on talent management, financial services, IPR support, product design and exhibition services are also offered.

The Tian An Cyber Park has strategic partnerships with Huawei and Tencent in the areas of cloud services and big data use. As part of the international cooperation, the Tian An Cyber Park has established a total of ten think tanks, so-called "International Business Express", with partners from the USA, Australia, France, Israel, England, Japan and South Korea. The Swiss company Logitech is located in a Business Express (Tian An Cyber Park 2019) .

As with all other science parks in China, internationalisation is actively pursued in Tian An Park. Among the advantages for foreign companies, the park management mentions tax benefits, information procurement and support from the local government, especially follow-up support for successful companies (interview 2019).

As was also confirmed in the interviews with German actors, access to reliable and up-to-date information is an important factor for the success of German companies (see Textbox 10). Without "guanxi" (relationships), one often cannot get the necessary information to use the existing economic instruments in China. Science Parks such as the Tian An Park offer information services for foreign companies. However, the success of internationalisation in Tian An is difficult to measure. In Dongguan, one of the Tian An locations, the proportion of foreign companies is only 10 %. This is probably due to the fact that the foreign companies are not familiar with the Chinese system and cannot assess what advantages they would get by locating in the park. *"The park is there to help the located companies cope with informal rules and unclear policies"* (Interview 2019).

Figure 41: Tian An Cyber Parks in China



Source: Tian An Cyber Park 2019

Organic island in Guangzhou

Guangzhou International Bio Island (GIBI) is the central hub of Guangzhou's biotechnology industry (consisting of Bio Island and Science City), which has been endorsed by the National Development and Reform Commission at the provincial level. The idea for the park was formulated in the Outline for Reform and Development Planning of Pearl River Delta Region in 2008. The opening of the Science Park was declared a national strategic project and a regional central construction project. The administrative committee of the Guangzhou Development District is the authority responsible for the park. The implementing Biotech Island Company is guided by the concept of the Guangzhou Development District and developed an all-round service system for enterprises in the park under the direction of the government. This includes various services, business consulting and the organisation of conferences and meetings. The park is a platform of the Guangzhou Development District and is used for the development of the "Sino-Singapore Guangzhou Knowledge City" and the "Guangzhou Science City". Established in 2010, Guangzhou International Bio Island Investment & Development Co., Ltd is responsible for investment, development and operation management and investment promotion for the Bio Island (Guangzhou International Bio Island (广州国际生物岛) 2019) .

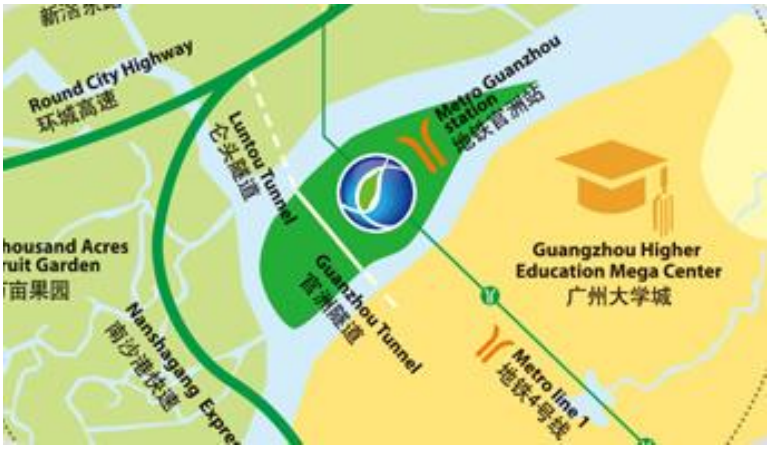
On 8 July 2011, the opening ceremony for the Guangzhou International Biotech Island took place. Covering an area of 1.83 km², the park focuses on the establishment of high-end biotech companies, R&D institutes focusing on biotechnology, biotechnology service companies and relevant financial investment organisations providing services such as investment and financing for the development of the biopharmaceutical industry. To date, more than 100 biotechnology companies have located here (Guangzhou International Bio Island (广州国际生物岛) 2019) .

Since the opening ceremony of the Bio-Island, several conferences have been organised for international biotechnology projects, such as "UK-China Health-tech Open Innovation Workshop", "Israel-China Science Bridges" or the Chinese Biopharmaceutical Association's presentation in the US. The Park is

actively involved in establishing international cooperation mechanisms with several countries such as the UK, USA, Israel, Switzerland, Cuba, Canada and the Netherlands. (Guangzhou International Bio Island (广州国际生物岛) 2019) .

Germany is also represented on the Bio Island. A Merck Innovation Hub in the sense of a business accelerator is to be opened in the Bio-Insel in November 2019. (Merck 2019) . With this, Merck aims to benefit from the existing innovation ecosystem of numerous technology companies, startups, universities, research institutes and related institutions in Guangdong Province. The ^{700m2} centre will house a presentation room showcasing the latest technologies, innovation projects and future research topics from the three business sectors. Merck has continuously invested in the development of innovation in China. For example, as part of the Merck Accelerator, programmes are run in Darmstadt and now also in China. Selected startups are offered the chance to first work on their project in the Innovation Hub in China and then develop it further in the Innovation Center at Merck's corporate headquarters in Darmstadt and explore the European market. *"China is a major hotspot for innovation and one of our most important growth markets. We are now building a strong platform here for Merck and our business partners to drive innovation in southern China. At the same time, we are strengthening our presence in this vibrant innovation ecosystem,"* said Kai Beckmann, Member of the Executive Board of Merck, during an interview of LABOs at the signing ceremony in Guangzhou (LABO 2018) .

Figure 42: Illustration of the Bio-Island in the city of Guangzhou



Source: Guangzhou International Bio Island (广州国际生物岛) 2019

Similar to Tian An Park, the internationalisation of the Guangzhou Bio Island is one of the goals of park development. There, too, the share of foreign companies is only 10 %. There are numerous funding opportunities for all companies. However, the subsidies are often decided on a so-called "case by case basis", so that not only foreign but also companies of overseas Chinese face the challenge of interpreting and understanding the non-transparent regulations. It is recommended to maintain intensive contact with key stakeholders to identify opportunities: *"Communication is everything. You always have to talk to the important people. It is often a matter of negotiation. Expecting clear guidelines is unrealistic"* (Interview 2019). The park administration also offers regular training seminars, including on current funding topics (Interview 2019).

5.3 Guangdong Province Innovation Tools

The measures of Guangdong Province are analysed as examples of the innovation-economic instruments actually available to foreigners. Some of them are quite similar to German offers. The province has published a *"Policy to further facilitate research and innovation"*, in which the so-called "12 golden articles" are named, which describe the measures with which Guangdong tries to make settlements attractive. (Department of Science and Technology, Guangdong Province (广东省科学技术厅) et al.

2015) :

1. Establishment of R&D subsidies for companies;
2. Pilot project Innovation Voucher;
3. Pilot project "Governmental Forward Commitment Procurement" on public procurement of innovative products and services;
4. Establishment of a risk compensation system for business incubators;
5. Establish a subsidy system for business incubators;
6. Improve land use policies for the construction of business incubators;
7. Support the further development of new R&D institutes;
8. Granting universities and research institutes the right to independently dispose of scientific and technological achievements;
9. Improve the incentive mechanism to implement technology transfer of scientific and technological achievements;
10. Improve the personal reward system for technology transfer of scientific and technological achievements in universities and research institutes;
11. Improve the assessment system to achieve a high professional qualification;
12. Improving housing provision for talented people.

5.3.1 R&D subsidies for companies

Relevant for foreign companies are business R&D subsidies. These can be obtained under the following conditions (Department of Science and Technology, Guangdong Province (广东省科学技术厅) et al. 2015) :

- For a company registered in Guangdong Province (excluding Shenzhen) with independent legal entity and sound financial management organisation;
- The company has already invested in research and development activities;
- The research activities carried out by the company must comply with central and regional guidelines in terms of subject matter and outcome, e.g. the two guidelines published by the Central Government Reform Commission "*The High-Tech Sectors Supported by the State*", "*Current Priority Development Guidelines for Key Sectors of the High-Tech Industry*";
- The implementation sites must be in Guangdong Province.

The annual support rate for enterprises is based on the application status of the enterprise and the provincial budget. In 2015, the share of possible support was 5% for an R&D expenditure of RMB 5 million or more (converted to mean that from an investment of about EUR 625,000, one can receive about EUR 31,000) and 10% for an R&D expenditure below RMB 5 million (i.e. EUR 60,000 for an investment of EUR 600,000) (Department of Science and Technology, Guangdong Province (广东省科学技术厅) et al. 2015). .

German companies do not invest in R&D at the beginning of their presence in China, but in trade, production and services. Only when the need for development work grows after some time, e.g. due to customer needs, do they invest in research (Interview 2019). Then the conditions in a "park" are usually economically more lucrative and administratively easier than outside. According to German industry representatives in China, different packages are then available for use depending on the park, city and province (Interview 2019).

Offers from provinces and parks are mainly available for company branches with technology development in China. The fact that these offers are not used by German companies to enter the Chinese market is also due to the fact that Chinese employees with industry experience are needed to use the opportunities and the necessary communication with the respective authorities and intermediaries (Interview 2019).

Innovation vouchers are government-issued securities that SMEs can use to purchase technology services from R&D institutes. The following companies are eligible to apply. (Department of Science and Technology, Guangdong Province (广东省科学技术厅) et al. 2015). :

- State-recognised high-tech companies;
- Companies that have received support from the innovation funds for SMEs at national, regional or city level in the last five years;
- Award-winning companies of a national, regional or city innovation and entrepreneurship competition sponsored by the relevant science and technology department;
- Enterprises that have received GB/T 29490-2013 (Scale for Management of Intellectual Property Rights of Enterprises);
- Companies that have successfully applied for patents or software copyrights in the last 5 years.

In Germany there are similar models of "innovation vouchers". One example at the federal level is the BMWi's "go-Inno" programme, which supports potential analyses, realisation concepts and project management with a maximum of EUR 5,500, EUR 13,750 and EUR 8,250 respectively. In addition, innovation vouchers are often used at Länder level. One example is the programme "Mittelstand.innovativ!“programme in NRW. In this programme, innovation consulting as well as implementation-oriented research and development activities are subsidised with a maximum of 10,000 and 15,000 euros respectively (internal communication DLR-PT).

Governmental Forward Commitment Procurement for innovative products and services is a contractual agreement between the government as buyer and companies to agree on procurement of yet-to-be-developed products in the future. The government commissions intermediary agencies that establish a kind of performance catalogue with producers for a product/service yet to be created and then agree on an acceptance of this product. This arrangement reduces the risk for a company to invest in an innovative development and offers the government to have a concrete influence on the product specification from the beginning. (Department of Science and Technology, Guangdong Province (广东省科学技术厅) et al. 2015). .

5.3.2 Business incubators

At the local level, a certain proportion of the city's planned land use can be used as construction land for a business incubator each year. To establish a business incubator, a legal entity must own at least 2,000 $^{m2\ of}$ useable land in Guangdong Province. A service team, an accompanying service offer and already 20 interested enterprises must be presented.

Venture capital institutions with financing and investment capacity in start-up companies in incubators receive risk compensation for their investment from local governments. In case of company insolvency, the provincial compensation fund will compensate the venture capital institution for the investment loss of 30% and the city compensation fund will compensate another 20%. Compensation at the provincial level for risk compensation or capital loss is a maximum of RMB 2 million (approx. EUR 250,000).

Financial institutions that have lent to enterprises within a business incubator are also covered against bad debts: up to 10% of bad debts are reimbursed by provincial and municipal credit risk compensation. The compensation from the provincial government for risk compensation or capital loss shall not exceed RMB 2 million (EUR 250,000). (Department of Science and Technology, Guangdong Province

(广东省科学技术厅) et al. 2015). .

5.3.3 Universities and research institutes

Universities and research institutes can decide for themselves how to use the income they generate through scientific and technological achievements. Patent use fees, profits from university-owned start-ups or spin-off companies can be freely used by the university without approval from the authorities. At least 50% of a patent profit should go to the inventor(s)/patent applicant(s). Filing patents, making profits and using them on the open market are important bases for assessing the university's technical competence (Department of Science and Technology, Guangdong Province (广东省科学技术厅) et al. 2015). .

In Germany, the Employee Invention Act applies nationwide. (Federal Office of Justice 2019) . Inventions made by an employee in the course of his or her employment belong to the company. In the law, there is a special paragraph for universities that entitles the inventor to 30% of the patent profits (Federal Office of Justice 2019) .

The establishment of new private R&D institutes will be further supported in Guangdong. The new type of R&D institutes is based on an enterprise model with the following characteristics:

- Independent legal entity,
- Diversified financing base also via investment companies,
- Build-up model according to the international standard,
- Market orientation and a modern management system.

The same guidelines apply to them as to the state scientific research institutes. They are eligible for tax relief and R&D subsidies. The start-ups are entitled to exemption from various tax burdens, e.g. import duties and import turnover tax, excise duty, etc. R&D expenditure financed from own resources can be subsidised up to 20 %, with a maximum of RMB 10 million (approx. EUR 1.125 million). (Department of Science and Technology, Guangdong Province (广东省科学技术厅) et al. 2015) . This is reminiscent of the Fraunhofer model with approx. 30 % basic funding, but the maximum amount is quite low: only rather small institutes are conceivable or educational institutes that are subsequently financed by fees and conduct research on the side.

5.3.4 Skilled workers and talents

In contrast to Germany, in China professional competence and expertise is more strongly represented by the job title. The guideline for evaluating "professional titles", which does not only refer to the academic degree (title evaluation index), should be understood against this background. Professional titles are therefore also dependent on how much funding a scientist obtains, how many awards he/she receives, how many publications are published. The academics are thus subject to a point system for their evaluation. (Department of Science and Technology, Guangdong Province (广东省科学技术厅) et al. 2015) .

Talent should be attracted to the region through the provision of suitable housing. This includes the construction of transitional housing or the purchase of commercial property for talents who do not have housing in the region. Furthermore, the use of state-owned building land can be used to build transitional or rental housing for talented people, and the purchase or leasing of commercial property for talented people with their own funds should be supported. (Department of Science and Technology, Guangdong Province (广东省科学技术厅) et al. 2015) .

5.4 Conclusion on R&I system functionality in China

The JCC initiative issued by the central government in February 2019 is subject to political and historical

evolution and is based on previous plans and initiatives. In particular, the GBA focuses on the strategy to deepen the integration of Hong Kong and Macao into China's economic system. The interplay between the strategies of the central government and the provincial government shows both top-down and bottom-up approaches, as the example of the HNTZ shows.

Guangdong Province, which largely forms the GBA, is the most innovative and economically strongest province in China. With its numerous HNTZs and science parks, it offers domestic and foreign companies numerous funding opportunities for their innovation activities. The innovation-economic support instruments are diverse and well-funded, as the so-called "Golden Rules" of the provincial government show. These instruments are aimed at companies, business incubators, universities and research institutes as well as skilled workers and talents in the region. If German companies meet the requirements, they can also make use of the benefits. However, the use of these instruments by foreign or German companies is more difficult. The reasons for this are the lack of contact with the competent authorities, insufficient Chinese language skills and the competence to understand and interpret the complex and partly non-transparent regulations.

However, the impact of the central strategy on the local level and its implementation cannot be derived from the example of Guangdong for the whole of China. This is because the economic and regional disparities of the provinces in China are large, especially between the economically strongest province like Guangdong and the other much weaker provinces. Even if the political and administrative structures of the provinces are similar, innovation policy measures depend on the respective province with its own financial possibilities.

The transferability of the "golden rules" mentioned here to Germany also requires a closer look at the framework conditions in Germany and the EU, which is not the subject of this study. Nevertheless, some of the instruments applied in Guangdong may be transferable with adaptation to local conditions and provide new food for thought: Forward procurement, comparable to innovative public procurement (see Chapter 2.6); the comparison of Chinese innovation vouchers with corresponding German offers; a closer look at tax credits or special deductions for (self-produced) intangible assets; the form of support for incubators; the incentive system for inventors in patents. The diverse talent programme of Guangdong province could also contain suggestions for Germany.

6. Foreign direct investment

With the purchase of the German robot manufacturer KUKA in 2016, Chinese foreign direct investment (FDI) in Germany came into the public eye. Previously, Chinese companies had already been active as investors, especially in European countries that had been heavily affected by the global economic and financial crisis since 2008, i.e. Greece, Italy and Portugal. As a reaction to the increasing Chinese direct investments in Germany and Europe, this development was observed and also evaluated with concern about political influence and technology outflow. (Jungbluth 2018, p. 8) . In 2018, the German government for the first time vetoed acquisitions of German companies by Chinese buyers, e.g. the planned takeover of the electricity grid operator 50 Hz by the state-owned State Grid Corporation of China (Felbermayr et al. 2019, p. 3) . According to Felbermayr et al. (2019, S. 3) the debate on Chinese FDI in Germany and Europe has so far been "rather devoid of evidence". The political discussions as well as the assessment with regard to the benefits and risks of Chinese investments require an analysis of the individual actors, their motives, the role of politics and also the economic interdependence of both countries. A central question is also whether the acquisition of German companies leads to increased technology transfer or even technology outflow to China. At the same time, German investments in China are relevant and the question arises whether the opportunities given in China can be used and in what form German interests are represented in China.

FDI occurs primarily in two forms: On the one hand, these are new establishments in the target country

to carry out production, sales or R&D ("greenfield" investments). The other is the acquisition of shares in existing companies up to the purchase of the entire company (mergers and acquisitions or M&A).

Basically, the mood of the German economy in 2019 is rather China-positive. According to a study by the Commerzbank AG (27.05.2019, p. 2), 30 % of the SMEs surveyed consider China to be a reliable trading partner. Against the backdrop of the trade conflict between the USA and China as well as Brexit and the resulting planning uncertainty, China is thus ahead of the USA (17 %) and the UK (8 %). (Commerzbank AG 27.05.2019, p. 2) . Around 2,000 German companies with an annual turnover of at least EUR 2 million were surveyed.

6.1 Economic policy background in China

Chinese foreign investments primarily serve economic goals, which are, however, complemented or also shaped by political goals. China's political goal is to compensate for the slowdown in economic growth at home since 2010 (World Bank 2019) at home through activities abroad. The liquidity accumulated through the export surpluses of the past years is used to acquire technologies in which there is currently a backlog. (Le Corre and Sepulchre 2016, p. xiii) . In some cases, trade policy factors also play a role when investments are made in order to circumvent tariff and non-tariff trade barriers. (Chen and Fang 2016, p. 3) . These include the advantage of being perceived as a domestic rather than a Chinese company. (Chen and Fang 2016, p. 6) . Other motives for FDI by Chinese private companies include market development, buying up competitors or suppliers, risk diversification and tapping into business characteristics/profiles of individual companies, but also circumventing weak domestic returns (Felbermayr et al. 2019, p. 5). For high-tech companies, e.g. from the IT sector, market access plays a more important role. Here, FDI often takes place via establishment investments (greenfield). For companies from the "mid-tech" sector, it is more a matter of knowledge and technology transfer. (Hans Böckler Foundation 2017, p. 12) .

Due to China's restrictive handling of foreign exchange transfers abroad, every foreign investment, even of a small size, must be reported and approved. Companies make sure that their foreign investments fit not only their own goals but also the Chinese government's technology and industrial policy objectives. Approval processes are then easier and more successful. Companies that invest in projects of political initiatives receive easier access to foreign exchange and are subject to facilitated capital controls. (Jungbluth 2018, p. 18) . To what extent companies with FDI actually pursue the government's political priorities or use this more as a side effect, for example to get easier and faster approvals for capital movements abroad, is impossible to judge. The simultaneous joint action of state, quasi-state and private actors shows a similar pattern in FDI as also in intra-China initiatives (see Chapter 2, Interviews 2019).

Made in China 2025 (MIC 2025)

The Made in China 2025 initiative described in chapter 2.2.3 aims at a technological catching-up process up to technology leadership in defined sectors. The tapping of foreign knowledge and technology potential through FDI is used as a transitional solution until China is able to develop and produce corresponding technologies itself. (Zenglein and Holzmann 2018). This includes investments in new R&D facilities (greenfield investments) in industrialised countries, as well as the acquisition of companies (M&A) with technological advantages (Wübbeke et al. 2016, p. 41) . When analysing Chinese direct investment in Germany and Europe, the question arises whether MIC 2025 or economic reasons are behind it. According to a study by the Bertelsmann Foundation, around 64 % of all Chinese investments in Germany can be assigned to the main areas of MIC 2025 (Jungbluth 2018, p. 17) .

Belt and Road Initiative (BRI)

As a strategic approach to China's international orientation, the Chinese Belt and Road Initiative (BRI) (described in more detail in Chapter 2.2.4) aims not only to open up new export markets and raw material suppliers, but also to build a positive China image through cultural exchange. (Islam 2019) . Technology

transfer to China, on the other hand, has not yet been a priority focus of the strategy. A reference to innovation-relevant investments abroad exists only in individual sub-aspects, e.g. within the framework of the so-called Digital Silk Road. This involves digitalisation, networking and the expansion of internet infrastructure in the countries along the Silk Road. (Chan 2019) . In the long term, BRI could influence Chinese FDI from cooperation on the use of Chinese Beidou satellites and through the development of common technological standards within the framework of the Digital Silk Road. (Chan 2019) .

Interplay of public and private investors and funding

In the course of China's economic reform, a variety of types of enterprises have emerged that are also active abroad as investors. An important role is played by state-controlled enterprises, which include *state-owned enterprises* (SOEs) that are managed and controlled by the state-owned asset trusts of the central and provincial governments (such as AVIC, Norinco, Weichai, XCMG). In addition, there are hybrid corporate forms with state anchor shareholders, the majority of whose shares are in free float on the capital market (e.g. CIMC, Shang Gong). The predominantly privately controlled companies include largely privatised former state-owned enterprises (Anhui Zhongding) and privately founded companies (Fosun, Jiangsu Jinsheng, Ningbo Joyson). (Hans Böckler Foundation 2017, p. 23) . Mergers of private companies are often forced by state authorities (o.A. 2019) . On average, 50-60% of all cumulative Chinese FDI in Europe between 2013 and 2018 came from state-controlled companies. (Hanemann et al. 2019, pp. 13-14) . These are capable of significantly larger transactions than privately controlled companies.

The links between the state and the private sector in China are difficult for outsiders to understand because they can also be informal (e.g. through internal party organisations or the appointment of party members to the executive and supervisory boards). (Jungbluth 2018, p. 19) . The state role in investment funds and investment management companies is sometimes obscured by opaque ownership and financing structures, so that they masquerade as private companies. An example of this is JIC Capital Management Ltd, which claims to be private but is owned by the State Council through several intermediary companies. JIC Capital Management Ltd. had a 51% stake in the acquisition of the Dutch semiconductor manufacturer NXP, alongside a private investor. (Wübbeke et al. 2016, pp. 51-53) . Huawei is considered an example of a nominally private company, but has been closely intertwined with the state apparatus and security agencies since its inception, and has been purposefully built as a national champion (Umback 2019, p. 7) .

An important contribution to the increase in FDI is made by Chinese state-owned banks through lending. These include the China Development Bank, the Export-Import Bank, the Bank of China, the China Bank of Construction and the Industrial and Commercial Bank of China. All of these banks have had branches in Europe since the beginning of the 2010s and offer Chinese investors great support for company acquisitions (Le Corre and Sepulchre 2016, p. 3) . The interest rates of the state-owned banks are in line with the market; what is more unusual is the amount of the loans (Le Corre and Sepulchre 2016, pp. 88-89) and the fact that it is sometimes easier for Chinese investors to obtain financing for FDI than for domestic transactions. FDI is therefore sometimes a *"second-best solution" from a* company's point of view. (Hans Böckler Foundation 2017, pp. 9-10) .

When investing abroad, the Chinese state can exert influence through various instruments: implicitly through plans and through expressed expectations that SOEs must meet and private firms want to meet, through easier lending, through controls on capital exports and also through investment funds. In the competition for high-tech companies, Chinese investors have competitive advantages through state influence. (Taube 2018a; Ifo Institute 2018, pp. 18-19) . However, despite the interconnections, it cannot necessarily be assumed that all Chinese foreign investors act on state directives. (o.A. 2019) .

In interviews with German industry intermediaries, doubts were expressed that Chinese companies pay higher prices for companies than other competitors due to state interconnection and therefore win the

contract. This may be true in individual cases, but not across the board (Interview 2019). One cause of higher purchase price offers by Chinese investors may be due to different methods of company valuation. Company valuations are carried out much more aggressively in China than in Germany, which can be seen, for example, in the valuation of market capitalisation in relation to turnover for listed companies. Investors from China pay more attention to the expected future development of the company. The companies active in Germany are usually listed in China and cannot justify excessive prices for investments to their shareholders (Interview 2019).

Indirect investment in Germany can occur through Chinese FDI in other countries: Chinese investors are involved in companies that take over German companies. As a result, these companies are then indirectly influenced by China. One example is the participation of the Chinese group Dongfeng in the French PSA Group, which in turn has a stake in Opel. These indirect takeovers by Chinese investors can hardly be controlled in the European internal market (Hans Böckler Foundation 2017, p. 9) .

Fear of Chinese FDI has increased in Germany and Europe in recent years. There are fears that China is consistently pursuing political motives through the participation or acquisition of technologically strong companies and that a technological sell-out in favour of China is taking place (Jungbluth 2018) . In particular, the targets set in the MIC 2025 for technological disclosure and the non-transparent state influence on companies give rise to this concern. More openness and greater transparency on the part of China with regard to state involvement in FDI is desirable and should be in China's interest, as the blanket condemnation of Chinese FDI would decrease. (Jungbluth 2016, pp. 35-36) .

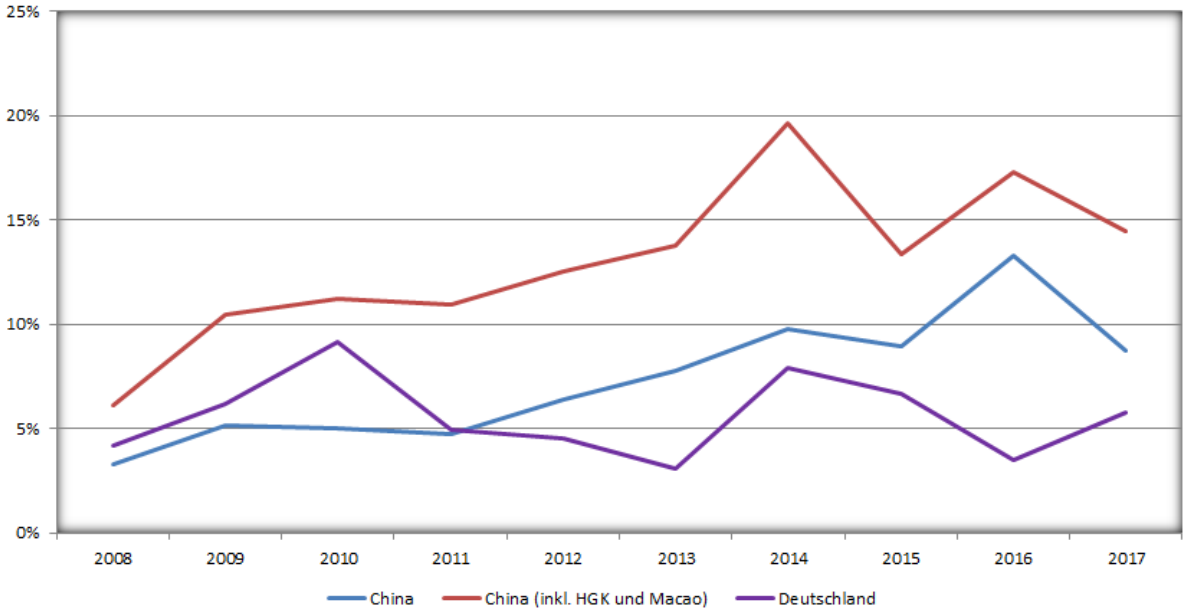
6.2 Development of Chinese direct investment abroad

FDI is often a next stage of development of previous foreign economic activities such as foreign trade. Unlike trade, they are usually long-term commercial activities. The group of countries whose firms act as foreign investors to a relevant extent is limited.

Activities of Chinese investors on a larger scale only started from 2010 onwards (Le Corre and Sepulchre 2016, pp. 1-2) . After having been one of the most important FDI destinations for a long time, China is now emerging as an important FDI source country, which also reflects the country's increased economic importance. In 2017, for example, China was the third most important FDI source country after the USA and Japan, with around USD 125 billion (approx. RMB 875 billion). (United Nations Conference on Trade and Development (UNCTAD) 2018, p. 6) . What is striking when looking at the development of China's FDI volume over time is that China still invested around 196 billion USD (approx. 1.37 trillion RMB) abroad in 2016. According to UNCTAD's World Investment Report, the decline is due to stronger government controls by the Chinese government to curb capital outflows abroad. These were introduced in 2016, particularly in response to FDI in sectors such as real estate, hotels and the entertainment industry. (United Nations Conference on Trade and Development (UNCTAD) 2018, p. 48) .

Globally, Hong Kong ranked fifth among countries with the highest FDI outflows in 2017, with USD 83 billion (approximately RMB 581 billion). Together, China and Hong Kong ranked second overall, ahead of Japan, with a combined volume of around USD 208 billion (approx. RMB 1.45 trillion) (United Nations Conference on Trade and Development (UNCTAD) 2018, p. 6) . The high value for Hong Kong is explained by Jungbluth (2016, S. 40) as the Hong Kong effect and can be explained by the fact that Chinese investors use subsidiaries in Hong Kong as a stopover for their FDI in order to circumvent the strict capital controls in China. Between 2009 and 2014, nearly half of China's capital flowed abroad through Hong Kong. In sixth place among the countries with the highest FDI outflows in 2017 was Germany, with around USD 82 billion (approx. RMB 574 billion). (United Nations Conference on Trade and Development (UNCTAD) 2018, p. 6) .

Figure 43: Share in global foreign direct investment (2008-2017)



Source: Own representation based on the data of the United Nations Conference on Trade and Development (UNCTAD) 2018

China and Hong Kong were the two largest FDI recipients worldwide after the USA in 2017, with a volume of USD 136 and 104 billion respectively (approx. RMB 952 and 728 billion). Germany ranked eleventh as a recipient country in 2017, with FDI totalling around USD 40 billion (approx. RMB 280 billion). (United Nations Conference on Trade and Development (UNCTAD) 2018, p. 4). .

Textbox 9: "Golden visas" for investors

Individual states grant citizenship or at least unlimited residence rights to foreign investors with "golden visas" if a certain investment volume is exceeded. In addition to numerous Caribbean states, the USA, Canada and EU member states such as Cyprus, Portugal, Latvia, Spain and Hungary also offer such programmes. The programmes differ greatly according to the amount of investment required: in France, more than ten million euros must be invested for a residence permit, while in Hungary and Greece an investment of more than 250,000 euros (approx. 2 million RMB) is already sufficient. (Xu et al. 2015) .

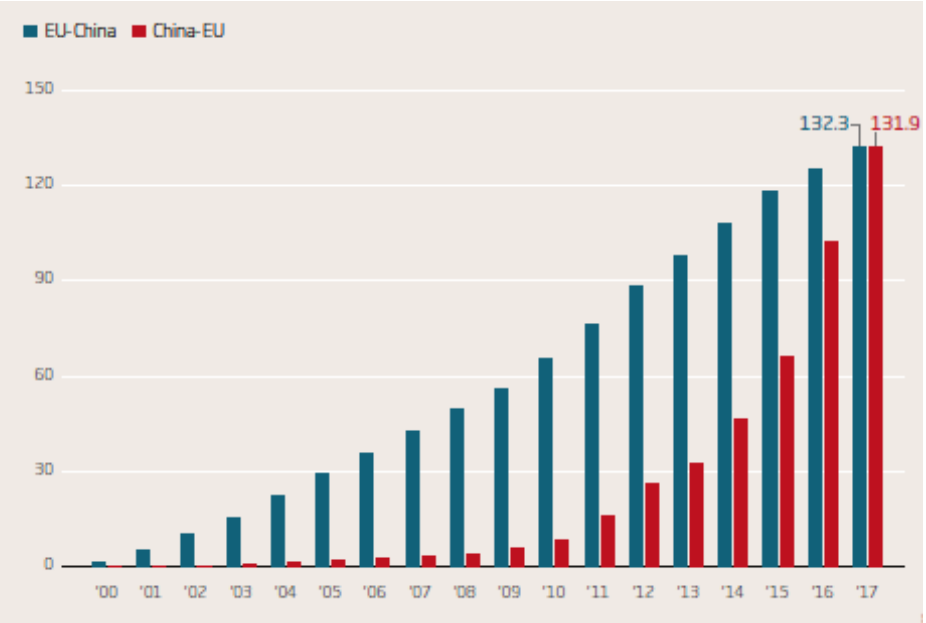
Chinese investors represent the largest group of investors in "golden visa" programmes (Xu et al. 2015) . Chinese investors are mainly looking for legal certainty. This type of FDI is very volatile and follows trends, for example in the selection of target countries. In addition, these investments are associated with a high risk of money laundering and tax evasion. For European countries, there is not much economic effect associated with these investments - often related to real estate acquisition - compared to otherwise motivated FDI. China loses a relatively large amount of capital in this way without receiving any economic countervalue.

The most important target regions for Chinese FDI outside Asia are North America and Western Europe as well as Australia, but Brazil and Russia are also important. The fact that emerging China is engaging in FDI in industrialised nations on this scale is a new phenomenon. Overall, the volume of Chinese FDI in the EU is now three to four times higher than the corresponding volume of EU investment in China. (Hanemann et al. 2019, p. 16) . The vast majority of this is in the form of mergers and acquisitions, with only 4.5% of investment in new companies. (Felbermayr et al. 2019, p. 15) . In 2016, EUR 37 billion (approx. RMB 296 billion) was invested; in 2017, around EUR 29.1 billion (approx. RMB 232.8 billion) was invested; and 2018, at EUR 17.3 billion (approx. RMB 138.4 billion), was the second year in a row

in which Chinese investment in the EU fell. (Hanemann et al. 2019, p. 9-10) . The total number of transactions also decreased from 247 in 2017 to 196 in 2018. (Ernst & Young 2019, p. 3) . European FDI in China was around EUR 10 billion (approximately RMB 80 billion) annually from 2011 to 2015. Since then, a decline has been observed.

Looking at the figures in Figure 44, we see that over 18 years there was a clear asymmetry in favour of European investment stocks in China. Since 2017, China's cumulative FDI stocks in the EU have caught up with the EU's corresponding stocks in China. The fairly stable steady annual growth rates of EU investment stocks in China and the strong Chinese increases in the EU in recent years are well visible.

Figure 44: Mutual investment stocks of China and the EU (2000-2017)[1)]



1) Figures in EUR billion
Source: Haneman, Thilo and Huotari, Mikko 2018, p. 17

In Europe (EU and non-EU), the UK (USD 81 billion, approx. RMB 567 billion), Germany (USD 41 billion, approx. RMB 287) and France (USD 25 billion, approx. RMB 175) account for 43% of Chinese investment since 2005, amounting to USD 343 billion. In a European comparison, Germany was third as a Chinese FDI destination country in 2018, and second in 2017 (Hanemann et al. 2019, pp. 11-12) . China is now the second largest non-European investor in Germany (Hans Böckler Foundation 2017, p. 11) . In 2017, Chinese FDI in Germany exceeded that of Germany in China for the first time . (Jungbluth 2018, p. 9) . In 2016, however, Chinese investors only made a total of around 0.4% of their foreign direct investment in Germany . (Jungbluth 2018, p. 14) . Including investors from Hong Kong, this figure rises to 0.7%.

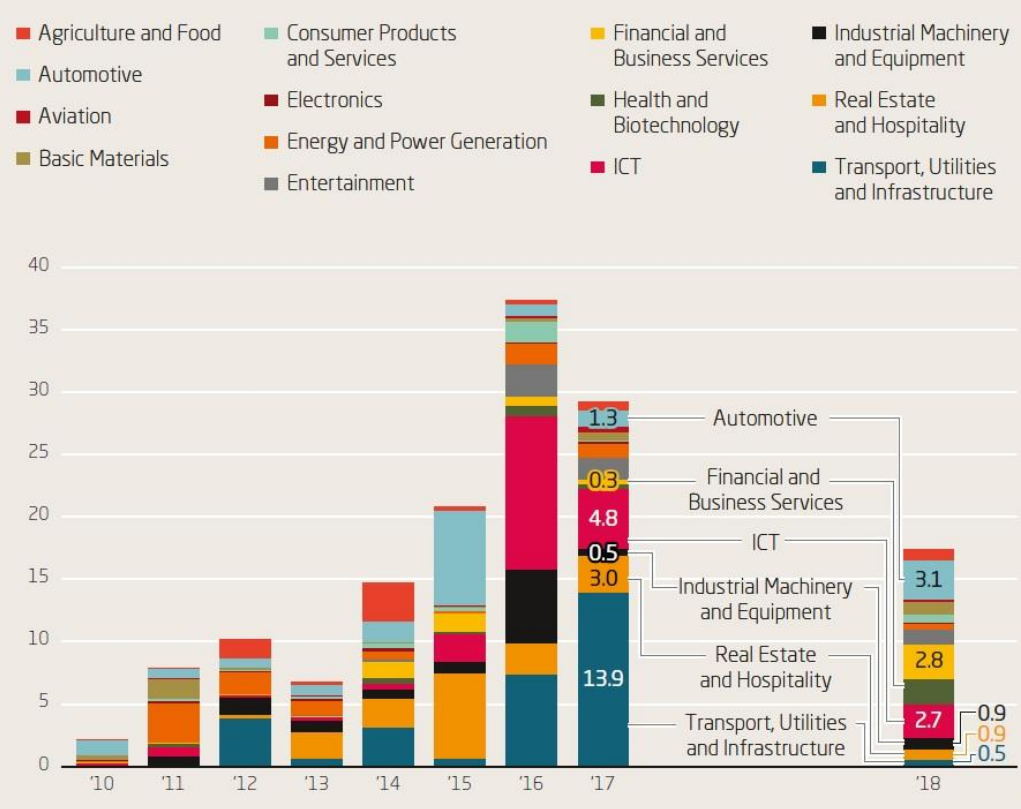
China has only been emerging as a relevant investor abroad for a decade, resulting from the country's economic growth and increasing economic openness. China is becoming increasingly politically and economically active in the global arena and must accordingly be taken seriously (Loesekrug-Pietri 2017). According to Loesekrug-Pietri (2019), Europe is not only "China's most important export market" but also "the first destination for Chinese investors", which is likely to become more pronounced in the near future in view of the trade conflict between the USA and China. China's expected increasing dependence on Europe as a reliable partner, according to Wübbeke et al. (2016, S. 9) Europe into a strong negotiating position on economic framework conditions. China's increased interest in Europe may be perceived by European decision-makers not only as threatening but as an opportunity to assert their own norms, values and interests. *"European government leaders, however, do not always play out*

this position of strength out of consideration for their interlocutors and the expected billions in investment" (Loesekrug-Pietri 2019) .

Sectoral focus in Europe

The breakdown of Chinese investment in the EU by economic sector shows changes after 2016 (see Figure 45): while the transport, infrastructure, real estate and ICT sectors show significant declines towards 2018, there was growth in the automotive, finance/services and health/biotechnology sectors (Hanemann et al. 2019, p. 13) . At the same time, a decline in particularly large individual investments was observed, and there is a balanced distribution of FDI across different sectors, so that no one sector accounts for more than 20% of the total (Hanemann et al. 2019, p. 13) .

Figure 45: Sectoral distribution of Chinese direct investment in the EU (2010-2018)[1)]



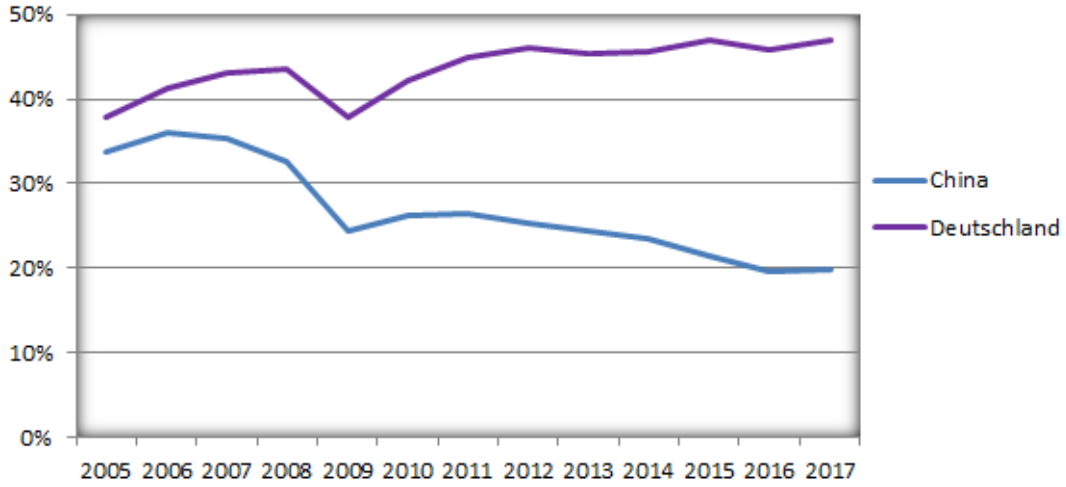
1) Figures in EUR bn
Source: Hanemann et al. 2019, p. 13

Of interest is the question of the extent to which the decision to invest in certain sectors is shaped by government plans and strategies such as Made in China 2025. The analysis of Chinese company investments by sector (see Figure 49) indicates a clear match with the political goals: 64 % of Chinese investments in Germany can be assigned to sectors that are named as crucial for the implementation of the MIC 2025 strategy. These sectors are in particular the automotive industry, mechanical engineering and robotics, energy systems and biomedical/medical technology. In the automotive sector, Chinese companies invest primarily in "newer" areas such as batteries, sensor technology or autonomous driving (Hanemann et al. 2019, p. 13) . However, this effect may also be influenced by the fact that these are the sectors in which Germany has strong and thus economically attractive companies. The high share of investment in MIC 2025 sectors cannot be clearly explained on the basis of current research. They may be motivated by government guidance and associated economic incentives, or by the high economic and technological relevance of the sectors. It can be assumed that there is an overlapping of political and economic reasons. (Jungbluth 2018, 17-18) .

6.3 Germany and China's foreign economic integration

Germany and China are export-oriented economies. Exports accounted for around 47% of GDP in Germany in 2017, and around 19.8% in China (World Bank 2019) . In 2005, exports still accounted for around one third of total economic output in both countries. In the years that followed, the export ratios diverged: while in Germany the export ratio continued to rise, in China the domestic share has grown since 2006 and the export ratio has fallen (see Figure 46). (World Bank 2019) .

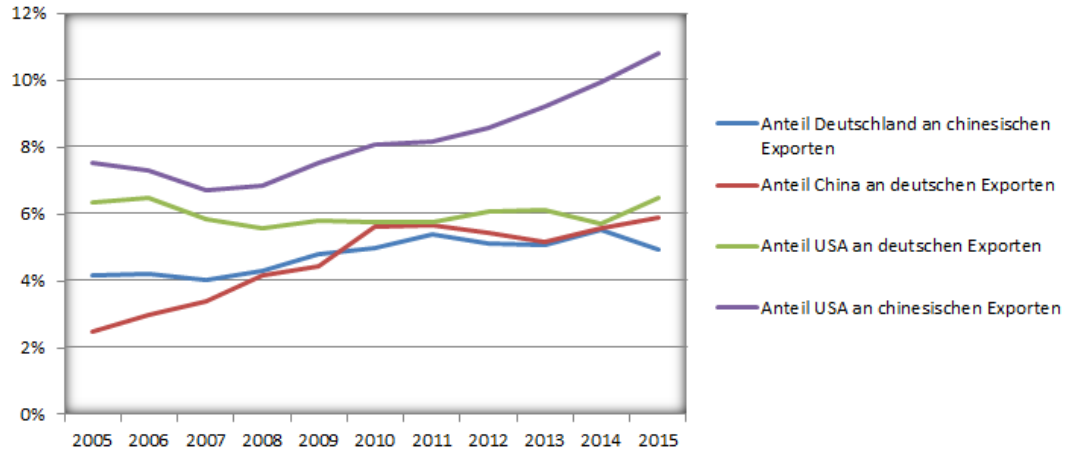
Figure 46: Export shares of GDP in Germany and China (2005-2017)[1)]



1) Figures in %.
Source: Own representation based on data from the World Bank 2019

Germany and China's exports are strongly intertwined. Both countries accounted for around 5 % of the partner country's exports in 2015. However, exports to the USA are of even greater importance for both countries, which means that both exporting countries are more dependent on import demand from the USA than from the other country. The share of German exports to China is rising (from 2% in 2005 to just under 5% ten years later), while it is stagnating around 6% to the USA. The share of Chinese exports to the USA is rising, while it has stagnated to Germany since 2011 (approx. 5.5%) (see Figure 47). (OECD) . US President Trump imposed tariffs on Chinese imports in 2018, which he increased again in May 2019. Tariffs of 25 % will be imposed on imported goods worth USD 200 billion. As a result, exports between China and the USA are expected to decline in the coming years. (Mildner and Schmucker 2019, p. 3) .

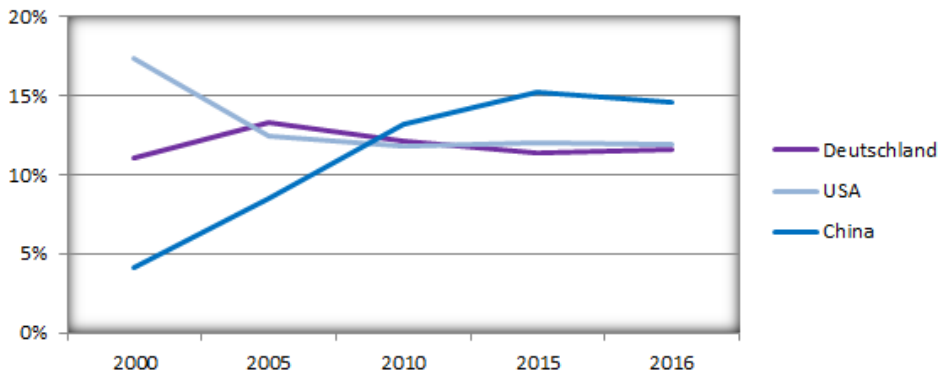
Figure 47: Country shares in total exports of China and Germany (2005-2015)[1)]



1) Figures in %.
Source: Own representation based on data from the OECD

The Federal Report on Research and Innovation defines the global trade share of research-intensive goods [8]as an indication of a country's competitiveness (Federal Ministry of Education and Research (BMBF) 2018a) . China is now the world's leading exporter of research-intensive goods. In 2017, China's global share (including Hong Kong) was around 15.2%, ahead of the US at 11.3% and Germany at 11.6% . (Gehrke and Schiersch 2019, p. 13) . *"[...] The export structure - differentiated by high-, medium- and low-tech goods - suggests a shift in China's export strategy towards high-tech products."* (Reinecke and Schmerer 2018, p. 13) . The increase in exports of research-intensive goods from China is evidence of China's increased integration into global value chains. When looking at specialisation in research-intensive exports, it can be seen that the US and Germany have a high share of research-intensive goods compared to the export of all manufactured goods. Although China is the world leader in the export of research-intensive goods, the share of China's total export is low (Gehrke and Schiersch 2019, pp. 16-18) . Exports to Germany are dominated by electronics and machinery (together accounting for more than 50% of Chinese exports to Germany. German exports to China are dominated by the automotive industry (a quarter of all exports to China) and mechanical engineering (a fifth) (Center for International Development at Harvard University 2019) .

Figure 48: Shares of global exports of research-intensive goods by China (incl. Hong Kong), Germany and the USA (2000-2016)[1)]



1) Figures in %.
Source: own representation based on data from United Nations (UN) 2019 ; quoted according to Gehrke and Schiersch 2019

Germany benefits *"as an exporter of high technology"* (Bartsch and Laudien 2016, p. 11) from China's large sales market. With regard to economic relations between Germany and China, the BDI in its policy paper of 2019 assesses a hypothetical economic unbundling between China and Germany as worrying: "This would be associated with enormous costs due to the strongly integrated value creation networks and the current position of German industry on the Chinese market as well as the existing potentials in business with China (Mair et al. 2019, p. 6) . Protectionist behaviour towards China, as seen by the USA, will therefore hurt Germany economically. *"Nevertheless, a certain degree of self-protection is necessary to prevent a sell-out of German interests based on unfair competitive conditions,"* says Jungbluth (2016, S. 35) . Germany should therefore insist more strongly on the dismantling of trade barriers and capital controls, on more market transparency and protection of intellectual property. (Bartsch and Laudien 2016, p. 11) .

[8] Research-intensive goods include cutting-edge technologies and high-value technologies (high technologies). *"Cutting-edge technology includes goods in the production of which more than seven per cent of turnover is spent on research and development on an annual average. High-value technology goods are goods in the production of which more than 2.5 per cent but less than 7 per cent of turnover is spent on research and development on an annual average"* (German Institute for Economic Research (DIW) 2019).

6.4 Chinese investments in Germany

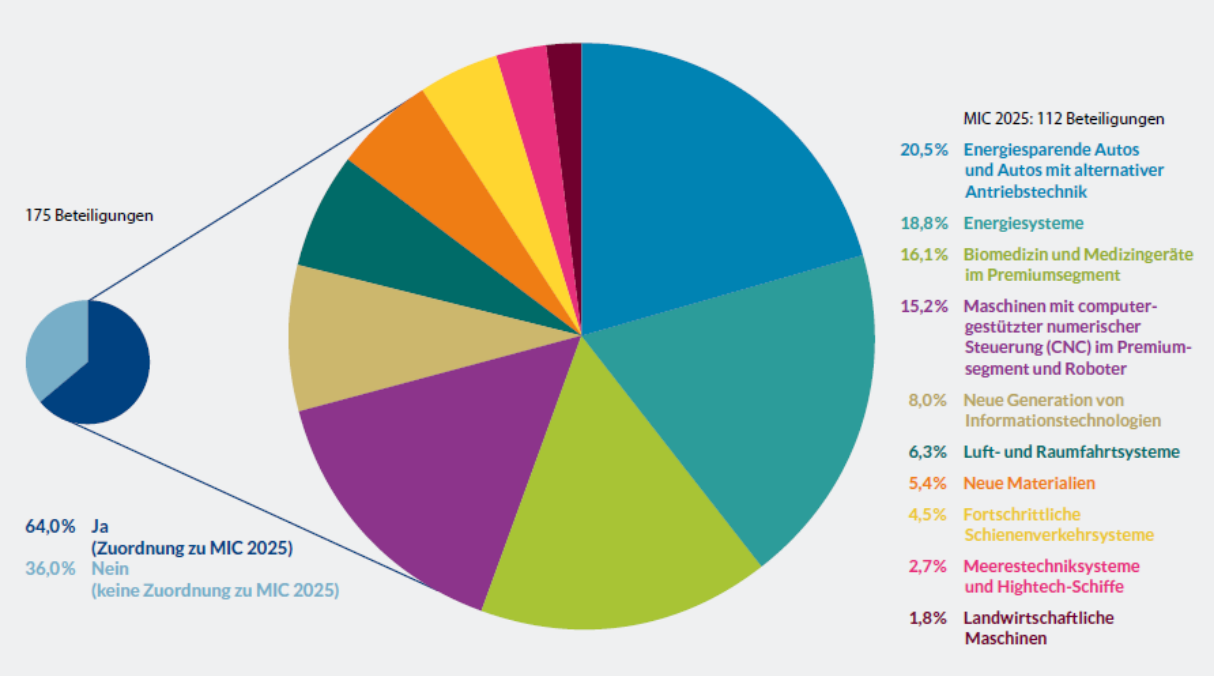
The purchase of and participation in existing companies accounts for around 82% of Chinese FDI activities in Germany, while new establishments account for around 18% (Welfens and Yushkova 2017, p. 14) . The investment volume is usually significantly larger in the case of acquisitions than in the case of new establishments. (Bartsch and Laudien 2016; Jungbluth 2016, p. 27) . However, investments in new establishments are usually associated with higher long-term economic added value for the target country, e.g. through newly created jobs or infrastructure. (Felbermayr et al. 2019, p. 7) .

An important motive for Chinese companies to relocate to Germany is proximity to industrial customers, as German companies increasingly see this connection to their Chinese suppliers as important (PricewaterhouseCoopers (PwC) 2015, p. 37) . In the case of investments and acquisitions by Chinese FDI, the investor in most cases comes from the same or a comparable industry as the acquired company (Hans Böckler Foundation 2017, p. 23) . The German target companies often fit the portfolio of the Chinese investors and are intended to help them gain a foothold in Europe. An important motive for takeovers is the reputation of German and European brand names, which, in contrast to Chinese brands, are internationally recognised. By tapping into established brand names and the positive image of "Made in Germany", Chinese companies gain advantages in international markets. (Le Corre and Sepulchre 2016, p. 79; Ernst & Young 2019, p. 16) .

Chinese investments in Germany usually follow existing business contacts, e.g. customer relationships. The Chinese entry is not sudden due to the existing interdependencies, but is the result of a lengthy negotiation process. These processes are accompanied and supported by consultancies and also frequently by the innovation agencies of the German federal states. In interviews, it was expressed that the current negatively coloured reporting in Germany on China is leading to significant uncertainty among Chinese investors. Chinese companies increasingly feel unwelcome or are afraid of negative reporting (Interview 2019).

In interviews with experts from business consulting, the area of Industry 4.0 and advanced manufacturing in particular was mentioned as a Chinese investment target in Germany. One reason for this is Germany's diversity and strength in this area, which is not the case with other target countries (Interview 2019).

Figure 49: Sectoral distribution of Chinese direct investment at MIC 2025 in Germany (2014-2017)[1)]



1) Figures in %.
Source: Jungbluth 2018, p. 17

When looking at Chinese investments in MIC 2025 sectors, according to a study by the Bertelsmann Foundation on Chinese FDI, there is (Jungbluth 2018) only shows a slightly higher share of state-owned enterprises (22% compared to 18% for all investments). The high share of investment by private companies in state-supported sectors can be explained by state incentives described above, such as easier access to foreign exchange and capital export controls. (Jungbluth 2018, pp. 18-19) . Another study by the CESifo Group (Fuest et al. 2019, p. 16) analysed Chinese investments worldwide according to whether they are influenced by the government's BRI and MIC 2025 strategies. This study shows that state-owned companies are more likely to take policy guidelines into account in their investments, while private companies follow economic interests.

Chinese investors mainly buy family businesses in the western federal states (Le Corre and Sepulchre 2016, p. 24) . Regional focal points of Chinese FDI in Germany are Baden-Württemberg and North Rhine-Westphalia, followed by Bavaria. These are basically the headquarters of many German firms, and in particular of many firms in the preferred sectors of Chinese investors. (Jungbluth 2018, p. 21) . The three federal states also have the highest patent intensity of the German federal states. The three states accounted for more than three quarters of all patent applications in Germany in 2018: Bavaria with 14,852 applications has a share of 31.9 %, Baden-Württemberg with 14,608 applications has a share of 31.3 % and North Rhine-Westphalia with 6,856 applications has a share of 14.7 %. (German Patent and Trade Mark Office (DPMA) 2019)). This makes the motive of technology acquisition understandable, especially for investments in Bavaria and Baden-Württemberg. The new federal states account for only 10 % of all Chinese investments. Here, investments are made primarily in Saxony and Thuringia. German companies often have high debt and lower profitability before being taken over by Chinese investors. (Fuest et al. 2019) . In this context, it was stated in interviews that in many cases companies were not owned by Germans before the acquisition by Chinese investors and that the purchase by Chinese investors is associated with hopes of a more stable development. Especially in the case of share acquisitions of German companies on the stock market, shares are acquired on the international stock market from different owners. According to statements by industry consultants, Chinese companies tend to have disadvantages here because Chinese capital market rules tend to hinder quick decisions (Interview 2019).

Innovation aspects

The takeover of German companies by Chinese (and other) investors is associated with the risk that knowledge and technology will flow to China and thus innovation and value creation potentials in Germany will be lost. The acquisition of a company is often accompanied by at least a partial relocation of learning and innovation processes to the investor's location. (Stiglitz and Greenwald 2015, p. 379) . With regard to Chinese parent companies, there are cases where the development of equipment is transferred to the parent company. However, the most important transfer channel seems to be the personal visit of employees from China to the German research and development departments. However, it is also apparent that the Chinese investors invest in R&D capacities in Germany to a greater extent than under the previous owners. (Hans Böckler Foundation 2017, pp. 17, 20) . In addition, Chinese companies are increasingly establishing R&D centres in Germany. One example is the new research and testing centre of ZCC Cutting Tools in Düsseldorf with about 20 new employees in research, development and testing. Previously, the company had R&D activities only in China. (NRW.Invest 2019) . Another example is Geely's new research centre in Hesse, where around 100 new jobs will be created in R&D for the automotive sector. (Investment Platform China / Germany 2019a) .

In a Dutch case study of a company takeover, the Chinese investors did not directly influence the R&D activities, but focused on the financial results of the company. There was no outflow of technologies to China or relocation of R&D capacity (Ferchen et al. 2018, p. 32) .

Effects on Germany as a business location

The establishment of new R&D locations by Chinese companies through greenfield investments has positive effects on Germany as a location for innovation (Welfens and Yushkova 2017, p. 14) . Huawei's European research centres, in which large investments have been made and which employ more than 1,200 people, are an integral part of the Group's innovation capacities. (Umback 2019, p. 8) . Overall, Germany is one of Huawei's preferred locations, according to founder and CEO Ren Zhengfei in a 2019 interview . (Balzli et al. 2019) .

Interviews with representatives of the innovation agencies of the federal states show that the federal states have an interest in foreign - including Chinese - direct investment. Previous experiences with Chinese investors have been predominantly positive. They are perceived as long-term oriented and reliable, with little influence on the German location. The innovation agencies are actively acquiring investors in China, e.g. through events, and in some cases also through a permanent presence in China. The federal states have different approaches depending on their economic strength, the costs (for example for real estate), or also the sector specialisations in different regions. Headquarters" or research departments are more likely to be considered in expensive, attractive cities, while production, sales or warehouses are more likely to be located in favourable regions (Interview 2019).

The aim of the agencies is to attract Chinese companies that fit into the economic structure of their own regions or cities. By creating a technology profile of their own strengths and needs and corresponding profiles of Chinese provinces, the agencies try to select and approach Chinese companies already in China so that they can be integrated as smoothly as possible into the value chains in a German region and come into contact with the German companies based there at an early stage. By actively approaching investors, it is primarily owner-managed, internationally open, SME-like companies in China that are addressed. With their acquisition strategy, German agencies also help Chinese investors to argue their case for capital export to the Chinese state. The companies are looked after after their investment in Germany. They actively try to use Chinese graduates of German universities as bridge builders (various interviews in 2019).

According to the representatives of the innovation agencies, Chinese investors behave significantly differently than Western investors and are rather passive. The reasons are cultural and also language problems. As long as the acquired companies generate profits, Chinese investors tend to interfere little in entrepreneurial decisions. As a result, the expectations of the German partners are often not met and opportunities are also missed. In contrast to German investments in China, where German companies familiarise themselves intensively with China and Chinese culture, similar behaviour is often not observed among Chinese investors so far (Interviews 2019).

For some of the German companies taken over, there are increased export opportunities in Asia in general and better access to the Chinese market in particular. (Jungbluth 2016, p. 32) . For example, Putzmeister, which was acquired by the Chinese Sany Group in 2012, benefits from the financial strength of the parent company. The latter in turn benefits from the innovations of the acquired company and uses these as a basis for acquiring further companies in the mechanical engineering sector. (Le Corre and Sepulchre 2016, p. 24) . Positive employment effects can be expected in the acquired companies. (Jungbluth 2016, p. 31) However, the actual number of jobs saved or created is difficult to quantify. In its statement on the hearing at the Bundestag's Committee for Economic Affairs and Energy on the handling of foreign investments, the BDI states: "*Chinese investors have investment holdings of 2.2 billion euros in Germany, which is only around 0.4 per cent of total foreign investments (2016). German investments in China are 35 times as high. Chinese investors control 139 companies in Germany, 16,630 employees work for Chinese-owned companies in this country. By contrast, 45 times more Chinese work for German investors in China."* (Bundesverband der Deutschen Industrie e.V. (BDI) 2019, P. 3) .

In the long term, the consequences for the acquired German companies could change. The development of, for example, the transfer of relevant technologies and patents to the Chinese parent company is difficult to predict. (Jungbluth 2016, p. 33) .

In view of China's relatively low investment volume in Germany, it is *"exaggerated to speak of a Chinese investment flood in which German companies are systematically and comprehensively bought up"*. (Felbermayr et al. 2019, pp. 24-25). . Even though China subsidises FDI in certain sectors and pursues economic policy goals, this has so far not proven harmful to Germany in terms of competitiveness and technology outflow, according to the BDI (Strack 2017, pp. 16-17). Moreover, it has been shown that Chinese FDI in Germany does have positive effects:

"Investments from China and other countries create jobs, bring capital into the country and contribute to tax revenue. Chinese investors also improve integration with the Chinese market, which is important for Germany. When investing in companies, Chinese companies bring a long-term interest compared to financial investors from other countries and in some cases offer location guarantees. In the past, they have already rescued German companies from insolvency. A fundamental openness and welcoming culture for foreign investors, regardless of their country of origin, must remain and possibly even be strengthened." (Jungbluth 2018, p. 6)

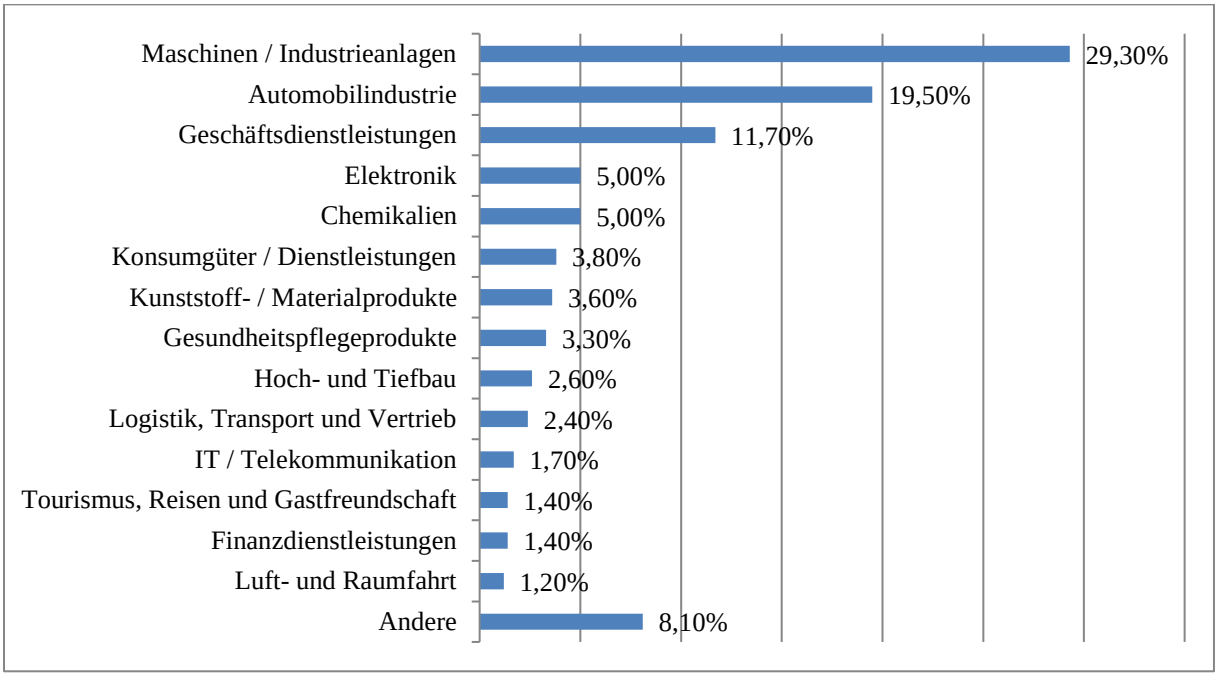
However, the public debate on Chinese FDI is often fear-based and loses sight of the potential opportunities. This can easily lead to compartmentalisation and fundamental scepticism or discrimination against China. Restrictions on access to Chinese investors, however, violate the principles of a liberal market economy and fair competition, as well as property rights and freedom of contract, and therefore cannot be in Germany's interest. (Bundesverband der Deutschen Industrie e.V. (BDI) 2019, P. 7) .

A Foreign Trade and Payments Ordinance issued by the Ministry of Economics on 29 December 2018 has tightened the review procedures for Chinese investments in Germany. The review procedure not only leads to longer review periods and higher costs, but also to more legal uncertainty due to an expanded scope of discretion. Kroymann (2019, S. 23) criticises that *"in terms of investment control, Germany is thus moving further towards the investment environment in China,* which has *been widely criticised by the German side"* and predicts *"that the number of Chinese company acquisitions in Germany will fall as a result of the latest amendments to the Foreign Trade Regulation"*. According to the BDI's assessment, *"investments that would have called into question the protection of public order and security"* were already sufficiently protected before the regulation was adapted (Strack 2017, pp. 16-17) .

6.5 Chinese market conditions for German companies

In addition to the general and continuous increase in bilateral trade volume between China and Germany, there has been an increase in Germany's direct investment in China since 2014. According to the Chinese Ministry of Commerce, Germany was the largest European investor in China at the end of 2018 with USD 33.4 billion (approx. RMB 233.8 billion). (Schmitt and Abele 2019) .

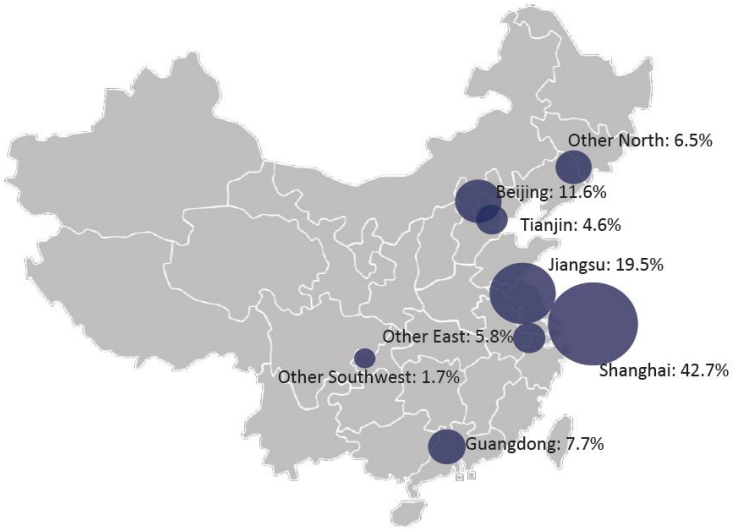
Figure 50: Shares of German companies in China by industrial sector (2017)



Source: own representation based on data from the German Chamber of Commerce in China 2018 , S. 10

According to the German Chamber of Commerce Abroad, around 5,200 companies from Germany were active in China in 2017. Shanghai remains the economic centre. Around 43 % of all German companies are located in eastern China, in the Yangtze delta. (Rödl&Partner 2018) . Other conurbations of German entrepreneurs can be found in Beijing, in the Bohai-Rim region in northern China and in the Pearl River Delta. (German Chamber of Commerce in China 2018, p. 8) . Most of the investments flow into companies in the manufacturing industries such as machinery and industrial equipment (29.3%), the automotive industry (19.5%) and business services (11.7%) (see Figure 50). (German Chamber of Commerce in China 2018, p. 10) .

Figure 51: Locations of German companies on the Chinese mainland



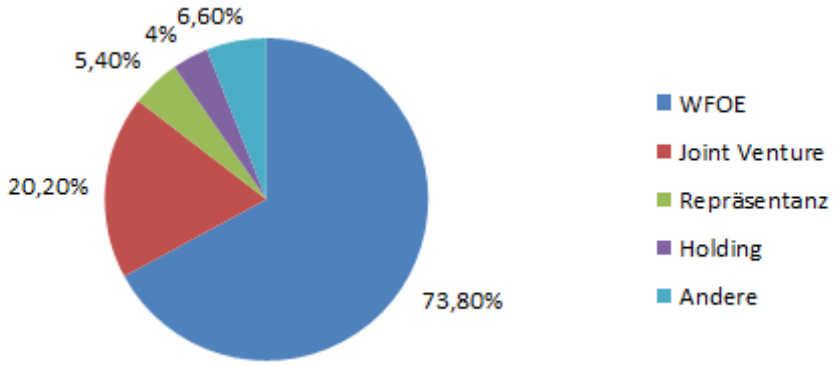
Source: German Chamber of Commerce in China 2018 , S. 8

In principle, foreign enterprises can operate in China in the following organisational forms under investment law: as a wholly foreign-owned enterprise (WFOE), as an equity joint venture (EJV) and as a cooperative/contractual joint venture (CJV). (Rödl&Partner 2018) . WFOE is comparable to the

German GmbH, whose shares are 100 % foreign-owned. It is the most common corporate form for FDI in China and is often a wholly owned subsidiary of the German company. In contrast, an EJV is a joint venture (JV) between a foreign and a Chinese partner. If the foreign shareholding is at least 25 %, this form of enterprise is associated with tax benefits. As a rule, corporations can be considered as Chinese partners. The second form of joint venture - CJV - is particularly suitable for short-term or project-related cooperation. In general, a joint venture only exists if there is at least one Chinese partner. (Rödl&Partner 2018, p. 15) .

Most German firms in China (73.8%) have the legal status of a WFOE, while 10.2% are organised as (Sino-German) joint ventures (EJV or CJV) (see Figure 52). Since 2015, the share of German WFOEs has increased (69.9 % in 2015). These figures refer to China and do not include companies located in Hong Kong and Macau.

Figure 52: Legal status of German companies in China in 2018



Source: German Chamber of Commerce in China 2018 , S. 8

According to the Business Confidence Survey 2018/19, published by the German Chamber of Commerce Abroad in China, the majority of German companies based in China (54.3 %) generate less than 5 % of their income through exports, but produce mainly for the local market and are therefore only marginally dependent on exports. Within export-active companies, only 5% report exporting 25% or more of total exports to the US (German Chamber of Commerce in China 2018, p. 22) . As a consequence, the Business Confidence Survey found that only one third of German companies based in China are either directly or indirectly affected by the current trade conflict between China and the US. (German Chamber of Commerce in China 2018, p. 23) .

Other current developments are influencing European FDI activities in China: On the one hand, the Chinese government is increasingly using "market opening rhetoric". (German Chamber of Commerce in China 2018, p. 6) is being used. There is talk of increased liberalisation of some regulations and the promotion of free market forces. (Publications Office of the European Union 2019, p. 53) . Nevertheless, according to the AHK, the regulatory framework in China continues to cause concern and is affecting the general business climate. Although 50 % of German companies believe the Chinese promises regarding market opening, the actual implementation of these promises is more sober than expected from the perspective of German investors. (German Chamber of Commerce in China 2018, p. 6) . On the other hand, according to the European Business Confidence Survey 2019 (European Chamber of Commerce in China 2019a, p. 16) Chinese companies were perceived to be as innovative as or more innovative than European companies for the first time in 2018. The Chinese market is perceived as advantageous by European companies mainly due to government incentives, low research costs and the productivity of local R&D teams (European Chamber of Commerce in China 2019a, p. 15-16) .

Textbox 10: Perceptions of German actors in China

Even though the list of challenges for Germans in China is long, the interviewees within the framework of the study assess their experiences and opportunities in China predominantly positively. The interviews focus on three questions and were answered as follows (essential statements are taken up):

How are the framework conditions for foreign companies perceived?

- The so-called "negative list" (see chapter 6.6) with currently 48 product areas makes market access for German companies in China more difficult. In addition, the central "Foreign Investment Law" is not ideally implemented due to local protectionism. Local governments have their own unwritten rules and treat local and foreign companies unequally. For example, foreign companies are not allowed to participate in the construction of "critical infrastructure". However, this term offers much room for interpretation and is exploited by some local governments and interpreted in a way that favours local companies even outside the 48 areas.
- In addition to IPR and legal certainty, there are Chinese regulations that are open to free interpretation and thus cause problems for foreign companies. Additional measures, such as some environmental requirements and fire safety regulations, are considered excessive, but cause additional costs. As Chinese companies often have good relations with the authorities, they are not treated as strictly as foreign companies.
- In addition, Chinese companies are better informed about when and how tenders are published.
- *"Framework conditions are not the same for everyone, but it is also difficult to demand equal conditions. That's where China wants to protect the state's interest. It's no different in Germany."*

What are the main challenges for German companies?

- The biggest challenge for German companies is still to find and retain qualified staff - both for administrative tasks and for production. One reason for this is the rising wage costs (6 % salary increase per year). Loyalty on the part of Chinese employees is also hardly to be expected.
- *Guanxi* (relationships) are still very important in China, especially in the second- and third-tier cities. Those who have guanxi get much faster access to information and can therefore react more quickly to current developments: *"The informal things are still very important. It is time-consuming and difficult to navigate such things."*
- There are other hurdles that foreign companies have to overcome that are not in the regulations, such as cloud computing: as a rule, foreign companies can work in the field, but their server must be located in China. Amazon, for example, has failed to participate in projects in this area.
- Through the Cyber Security Law (see chapter 2.7.1) there is even more unequal treatment: *"the Chinese companies enjoy full freedom in Europe, while the European companies have no access to websites like Google. Secure data transfer is by no means guaranteed."*
- Problems with the rule of law, cultural aspects and strong state control are also mentioned as problem areas.

How do you perceive the opportunities for German companies in China?

- IPR has been significantly improved in China in recent years. In court cases, it can be observed that some results are very positive. This means that the intellectual property of

German companies is better protected.

- Foreign companies generally do not get any special favours: *"the time when you got many advantages as a foreign company is now over".* Tax advantages and general location benefits are offered by some provinces such as Hainan, Guangdong or the Free Trade Zones, although German companies still have to comply with the often opaque regulations of the local governments.
- With Made in China 2025, foreign companies can get market shares in ten segments. In individual cases, German companies are also promoted. However, access to funding often only comes through guanxi to the local government. For SMEs, it is particularly difficult to obtain information about the subsidies in good time, because unlike large companies, SMEs cannot afford their own government relations departments that deal intensively with information procurement and analysis.
- In the Belt and Road Initiative, the tenders are not transparent and Chinese are preferred. *"Even if you get in, the standard of social security, for example, is not the same as the German standard, so problems arise in the implementation."*
- Despite everything, German companies have enough opportunities in China simply because of the size of the market. Moreover, the Chinese government is very good at artificially increasing demand in the country.
- *"In the last 10 years, Germany has already had a big piece of the pie."* If you understand the Chinese market better, you can still gain a lot.

In general, around 40% of German companies in China currently see an improvement in China's economic development. However, this percentage has fallen compared to previous years. With regard to future economic developments, 30 % expect a worsening of the situation. (German Chamber of Commerce in China 2018, p. 12) . Due to rising labour costs, the expected decline in economic growth and the lack of regulatory transparency, predictability and objectivity, one third of the companies say they have no plans to invest in the Chinese location within the next two years. (German Chamber of Commerce in China 2018, p. 20) .

As a result of a lack of systematic recording of the R&D activities of German companies in China, it is difficult to make statements about motivation, future plans and the nature of investments in research. (Czernich 2014, p. 2) . General reasons for relocating domestic R&D activities to a foreign location are market development, tapping specific knowledge or skilled labour, and savings in wages and non-wage labour costs. (Czernich 2014, pp. 9-10) .

The internationalisation of German R&D has increased in recent years. China is an important target country for German companies (Czernich 2014, p. 7) . Companies such as BASF, Bayer, Continental, Daimler, SAP, Siemens, VW and Wacker are increasingly operating R&D centres in China in order to be able to respond directly to specific local customer requirements. (Abele 2019a) . The Asian presence of many German companies is becoming increasingly important, according to data from Abele (2019a) will continue to be expanded: BASF, for example, plans to transfer about 25% of its current 10,650 R&D personnel from Germany to Asia by 2020, about half of them to China. Siemens, too, wants to take advantage of China's development potential and expand an R&D centre for mass transit signalling in Fuzhou, in Futian province. Siemens is relying on tailored R&D development work and the training and further education of local personnel. (Investment Platform China / Germany 2019b) . With its three plants in the north-east of the People's Republic, BMW is benefiting above all from China's affinity for innovation: in May 2019, BMW became the first international automotive group to receive a licence from the authorities in Shanghai to test autonomous driving systems under real-life conditions on Shanghai roads. As a result, BMW has been building a new research centre for this purpose at its

Shanghai site since June. (Investment Platform China / Germany 2019a) .

Relocating R&D activities to China is attractive for German companies due to various incentives: the Chinese government lures with tax incentives in the R&D sector, relatively cheap and qualified technical personnel are available, and companies with a Chinese R&D location benefit from local knowledge (INS Global Expansion Simplified 2018). China continues to have attractive framework conditions for a thriving innovation system: The size of the market, homogeneity in terms of language, culture and time zone, as well as technology openness allow for good scaling options and exploitable opportunities for investors (McKinsey Global Institute 2015) .

In interviews, German actors in China point out that R&D investments are not suitable for initial entry into the Chinese market. Only when there is a certain knowledge of the market and the customers, an understanding of the regulatory framework has been built up and suitable Chinese employees are in the company, do the next steps towards technology development and then possibly also research follow if necessary (interviews 2019).

German companies are increasingly setting up subsidiaries in China, no longer just to save production costs through low wages, but primarily to tap into the Chinese market, and to conduct R&D activities (INS Global Expansion Simplified 2018) . Among other things, this enables them to serve demanding local customers more effectively, faster and at lower cost, and to test innovations under unique conditions (market size, efficient network of suppliers, openness to innovation, etc.). (McKinsey Global Institute 2015, 107; Abele 2019a) . Wübbeke et al. (2016, S. 10) However, we recommend that companies exercise caution, especially in R&D activities in critical technology fields, as data and intellectual property are less well secured in China.

6.6 Barriers to entry in China

There is no open market for foreign investors in China (German Chamber of Commerce in China 2018, p. 5) . Although German companies perceive China's development positively, trade and investment restrictions continue to hamper foreign investors' access to the Chinese market. Chinese companies, on the other hand, enjoy relatively free access to the EU's internal market. (Publications Office of the European Union 2019; Hanemann et al. 2019) .

As already mentioned, there are visible and invisible *playing field asymmetries*. They range from unequal access to capital and subsidies, to systematic disadvantages through regulations, to financial advantages for domestic actors. Public procurement measures and industrial subsidies can be mentioned here as examples of systematic preferential treatment of domestic companies. (Publications Office of the European Union 2019) . A subdued business outlook and a challenging regulatory environment characterise the current business climate of German companies. (German Chamber of Commerce in China 2018 , S.5). German companies in China name the following problem areas (compilation from three sources) (German Chamber of Commerce in China 2018) ; (Hanemann and Huotari 2018) ; (Glattner 2017)):

- Lack of reciprocity due to market access barriers
- No access to certain sectors of the economy; in certain areas only minority shareholdings possible
- Joint venture compulsion in individual sectors
- Discrimination of foreign companies against domestic ones
- No equal access of foreign companies to public tenders
- Competition with state-subsidised companies
- Compulsion to transfer technology

- Data protection and data security
- Protection of intellectual property
- Limited access to fast internet
- Lengthy approval procedures
- Monetary affairs

In a 2019 study, the American Chamber of Commerce explains that (The American Chamber of Commerce in the People's Republic of China 2019, p. 8) that technology and R&D-intensive industries in particular face significant challenges from inadequate intellectual property protection, restrictive cybersecurity laws, and unique Chinese standards. The July 2017 Cybersecurity Law, which among other things authorises the Cyberspace Administration of China (CAC) to disclose source code, inhibits innovation and investment. (Shi-Kupfer and Ohlberg 2019, p. 23) . Due to structural restrictions, China ranks above the OECD average in terms of FDI restrictions in the OECD FDI Restrictiveness Index. (OECD) .

In order to ensure the competitiveness of German and European industry through legal certainty in data transfer issues, these challenges must be addressed quickly (Shi-Kupfer and Ohlberg 2019, p. 48; Reisach 2017, pp. 42-43). . Discussions with China on the legal situation regarding cross-border data flows, cybersecurity and e-commerce can be addressed at the German-Chinese level in the bilateral cybersecurity dialogue. The panel met for the first time in Beijing in May 2018. Strack (2018, S. 49) proposes holding additional event-related bilateral meetings and establishing contact points in Germany and China. A comparable formal dialogue on cybersecurity issues is, according to the Shi-Kupfer and Ohlberg (2019, S. 40) is also necessary at EU level. The EU Agency for Cybersecurity (ENISA) should be strengthened in its mandate to ensure the application of applicable international law on cybersecurity. EU-wide rules on risk assessment and measures for sanctions against cyber attacks should also be formulated. (Shi-Kupfer and Ohlberg 2019, pp. 47-48) .

One of China's most significant barriers to entry is the investment guidance catalogue for foreign investors. From 1995 to 2015, industries were divided into three categories: *encouraged*, *restricted*, or *prohibited.* Industries in the first category were officially supported by the Chinese government, with the foreign investor receiving tax incentives for their involvement in China. In restricted industries, different Chinese requirements for the investment were to be expected. Prohibited sectors were not open to FDI, but in all remaining industries, investment was largely free of conditions. As a formal prerequisite for setting up a company, approval by the Ministry of Commerce (MOFCOM) was mandatory, which often led to changes in the negotiated foundation agreements (Glatter 2017, p. 2) .

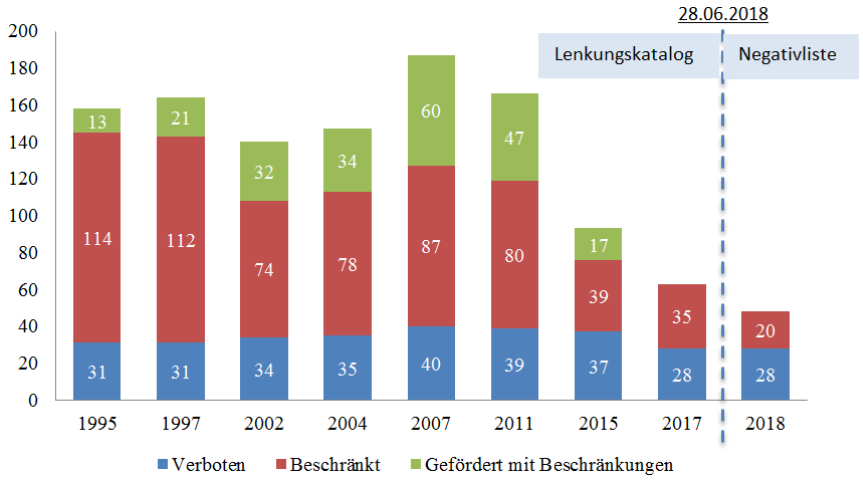
In the course of the above-mentioned period, the steering catalogue was amended five times in accordance with the economic policy objectives of the Chinese government. The document was also adapted in the wake of China's accession to the WTO in 2001 and the resulting obligations. (Glatter 2017, p. 2) . A structural change took place in July 2017 with the new Guidance Catalogue. The restructuring now provides for two components of the Steering Catalogue: A list of industries that are promoted and a negative list. (General Office of the State Council (国务院办公厅) 2017) . In addition, MOFCOM approval is no longer required, only registration with the State Administration for Industry and Commerce (SAIC). MOFCOM approval will still be required for FDI by enterprises in sectors included in the negative list, or in the case of an enterprise merger. (Glatter 2017, p. 2) .

The negative list has been revised several times and in its latest version (as of July 2019) contains 40 restricted and prohibited sectors (Ministry of Commerce (中华人民共和国商务部) 2019) . Currently, these include mining, energy, telecommunications, health care, publishing and education. (Weidlich 2019) . The following sectors have been completely removed from the negative list and are now open to foreign investors: Oil and gas exploration, other manufacturing, maritime transport, species

conservation, manufacturing, film distribution and screening, and cultural entertainment. However, it remains prohibited to invest in artistic groups (European Chamber of Commerce in China 2019b) . The list is supplemented by the "Negative List for Market Access" of 21 December 2018. This lists prohibited and restricted industries and projects that apply equally to both domestic and foreign investors (Scheil 2019, p. 30) .

Overall, the number of restricted and prohibited sectors for FDI has decreased significantly after 2015. From 1997 to 2011, a minimum of 108 and a maximum of 143 sectors were defined as prohibited or restricted, and up to 60 more sectors were promoted with restrictions (see Figure 53). In 2015, the number of prohibited and restricted sectors dropped to 76, in 2017 it was 63 and after the publication of the negative list only 48 (Weidlich 2019) .

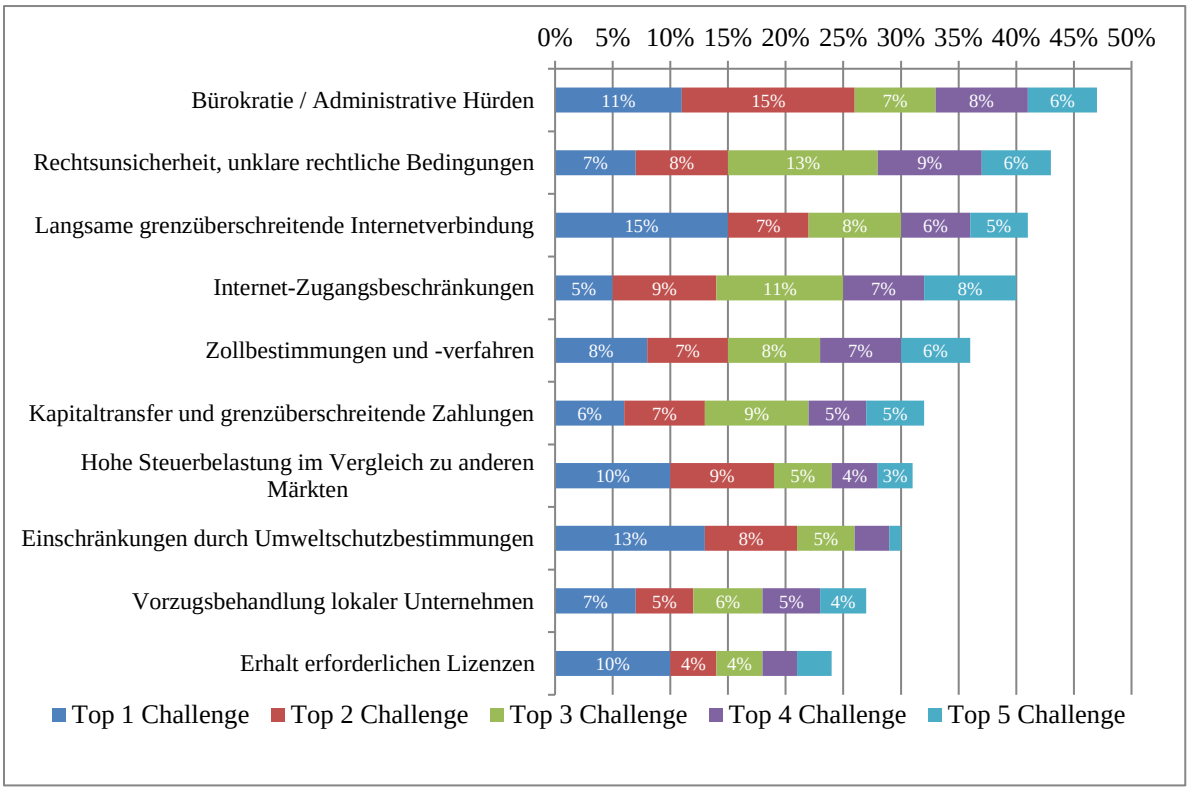
Figure 53: Number of restricted and prohibited sectors for FDI (1995-2018)



Verboten = prohibited, Beschränkt = restricted, Gefördert mit Beschränkungen = Promoted with restrictions, Lenkungskatalog = Steering Catalog, Negativliste = Negative List
Source: Weidlich 2019

Other market access regulations outside the steering catalogue include a number of further catalogues, lists and provisions to be observed depending on the industry, location and investment volume (Glatter 2017, p. 3) . This leads to 47 % of German companies citing administrative hurdles as the greatest regulatory challenge in business practice, followed by legal uncertainties and unclear framework conditions (43 %) (see Figure 54) (German Chamber of Commerce in China 2018, p. 27) .

Figure 54: Top 10 regulatory business challenges from the perspective of German entrepreneurs in China



Source: German Chamber of Commerce in China 2018, p. 27

On 15 March 2019, the second session of the 13th National Congress passed China's new Foreign Investment Law (FIL), which is scheduled to come into force on 1 January 2020. The new law combines and replaces three existing laws: the Sino-Foreign Equity Joint Venture Law, the Sino-Foreign Contractual Joint Ventures Law and the Wholly Foreign Owned Enterprises Law. The FIL is intended to create a greater level playing field between Chinese and foreign enterprises and provide a comprehensive legal basis for future investment and business activities by foreign players (Weidlich 2019, p. 26) .

The contents of the FIL cover all activities of foreign investors and companies, including WFOEs and JVs, as well as investors active in Hong Kong, Macao and Taiwan. As a concession to international pressure, it includes, for example, provisions prohibiting Chinese JV partners from stealing intellectual property or trade secrets (Article 22, FIL). In addition, the FIL prohibits government officials from taking administrative measures to carry out forced technology transfers (Article 22, FIL) and makes them criminally liable in case of non-compliance (Article 39, FIL). Furthermore, foreign investors are granted equal treatment in applying for licences (Article 30) and in public procurement (Article 16, FIL). (Chipman Koty 2019; National People's Congress 2019) .

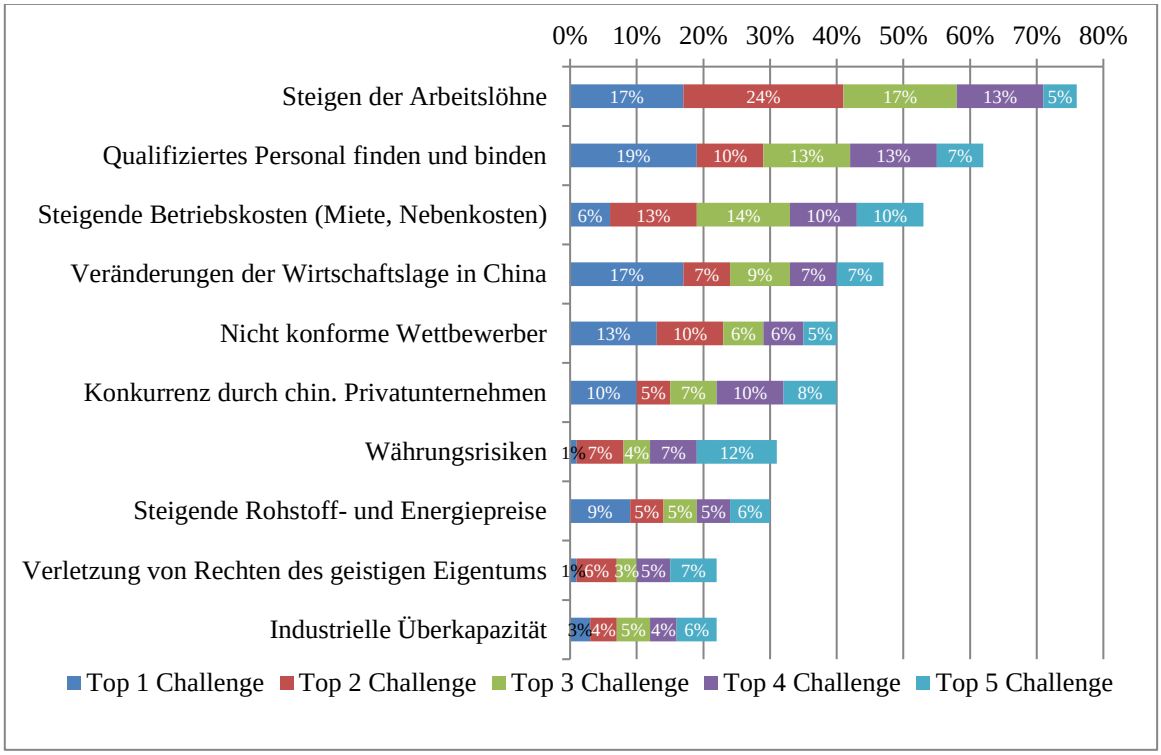
The central points of the FIL are the improved protection of property rights when investing in China and the principle of national treatment outside the negative list. (Rödl&Partner 2018) . However, potential market access barriers remain. The negative list (Article 28, FIL) continues to apply despite the reduction of prohibited or restricted industries, and a state security check for foreign investments is to be introduced (Article 35, FIL). In addition, antitrust requirements apply (Article 33, FIL) as well as special licences in certain industries (Article 30, FIL). The reciprocity clause in Article 40, FIL, states that in the event of a discriminatory or restrictive measure against Chinese investors by foreign partners, China may take "*corresponding measures*" against the foreign partner. (National People's Congress 2019) . This clause leaves room for interpretation due to its vague wording. (Rödl&Partner 2018) .

Another example of legal uncertainty is the "opening clause" of most normative documents in China, which [9]concludes with the words“ [...] *and* others, as provided by *other/relevant laws* and regulations", thus also giving the Chinese administration a wide scope for interpretation. As any number of other regulations and laws can be referred to, this clause creates great uncertainty among foreign investors. (European Chamber of Commerce in China 2019a, p. 27) .

Ambiguous frameworks, constantly changing catalogues, lists and regulations, as well as a perceived discrepancy between legal texts and practical implementation (various interviews in 2019) make long-term planning, risk prevention and communication with German headquarters difficult for foreign investors. Uncertainties and additional financial burdens are the result of this vague regulatory framework (European Chamber of Commerce in China 2019a, p. 24) .

In addition to the regulatory challenges already mentioned, such as bureaucratic hurdles and lack of clarity in the legal environment, operational challenges are also a major problem in market access. These include the search for qualified personnel (63%), lack of employee loyalty to the group and rising personnel costs (76%) (see Figure 55). (German Chamber of Commerce in China 2018, p. 29) .

Figure 55: Top 10 operational business challenges in China from the perspective of German entrepreneurs



Source: German Chamber of Commerce in China 2018, p. 29

As a further restriction, the Chinese database-based "Social Scoring System" could have an impact on foreign companies in China in the future. The scoring system aims to monitor and control individuals, companies and organisations. Information on creditworthiness, criminal records and social and political behaviour is used. However, the sources of the data and their evaluation standards are unclear. This is one of the reasons why the system is viewed very critically by the West. (European Chamber of Commerce in China 2019c) . Pilot projects are currently running in individual cities. From 2020, it is to be rolled out on a large scale in China. The European Chamber of Commerce in China (2019c) expects significant disruption to all businesses in China as a result of the large-scale roll-out in 2020.

[9] For example: 汽车产业投资管理规定 (Regulations on Investment in the Automotive Industry), NDRC, 10 Dec 2018 http://www.chinalaw.gov.cn/Department/content/2018-12/10/594_230928.html (Last checked 22 Oct 2019).

The legal framework in China on competition and antitrust law, consumer protection, cybersecurity, etc. is changing rapidly and is often confusing. Foreign companies wishing to invest in China *"should familiarise themselves with the new or expected regulations and [...] have resources ready to analyse and deal with legal issues"*, because violations of regulations and approvals (such as those of MOFCOM) can incur heavy penalties (Glatter 2017, pp. 1-2) .

Companies from Germany active in China can take advantage of policy-making opportunities in China by participating in international working groups, commenting on China's draft regulations and exchanging views with authorities and industry partners. (Wübbeke et al. 2016, p. 9; Kessler and Blöchl 2018) . Such engagement can help actors on the ground and in Germany to get better information on economic policy strategies. (Wübbeke et al. 2016, p. 9) .

China's investment restrictions put foreign companies at a competitive disadvantage: *"Chinese companies benefit considerably from the open markets and non-discriminatory FDI regimes in Germany and other European countries. Conversely, foreign companies in China are still formally and informally discriminated against compared to domestic companies. This situation illustrates that while the asymmetry in investment relations between China and Germany is quantitatively to China's disadvantage, qualitatively Germany is clearly at a disadvantage."* (Jungbluth 2016, p. 35) .

External political pressure is needed to persuade China to relax investment restrictions and implement reform promises to protect against technology outflows for international companies (European Chamber of Commerce in China 2019a, p. 8; Publications Office of the European Union 2019, p. 53) . Germany can address this in bilateral negotiations, but a pan-European insistence on reciprocity can build much more pressure. (Loesekrug-Pietri 2019) .

"In the past, Germany has relied on bilateral negotiations and rounds of talks with China. Progress, for example on equal market access, has not always been satisfactory. However, as Germany and other EU countries gain importance as an investment destination for Chinese companies, a new lever for more reciprocity could emerge." (Jungbluth 2016, p. 35)

6.7 Conclusion: Opportunities and challenges of Chinese FDI

Looking at the literature, the impression is that Chinese investments in Europe and Germany tend to have a positive effect and have not yet reached a level that would lead one to expect critical, negative effects for the economy (Löchel 2018, pp. 10-11; Bundesverband der Deutschen Industrie e.V. (BDI) 2019, p. 6; European Chamber of Commerce in China 2019a, p. 17; Jungbluth 2018). . After the peak of Chinese FDI in 2016, there were adjustments on both the Chinese and the European side. In China, for example, the requirements for foreign investments have been tightened and in Europe a more critical examination of Chinese investments has begun. The authors mentioned above point out that European regulation must take into account that Chinese (and also non-Chinese) investments in Europe are fundamentally welcome and have positive economic consequences. An investment review should not be a politically protectionist measure and should not be perceived as such, because a further opening of the Chinese market is only realistic if Europe itself does not start closing itself off to the outside world. At the same time, Europe must take a critical look at China's most recent concessions in the opening of individual industries within the framework of FDI in the coming period and examine them. If necessary, further renegotiations are needed to achieve fair conditions for European investors in China.

6.7.1 Opportunities

From the point of view of business and business organisations, the positive aspects of Chinese FDI outweigh the negative. For example, in a policy paper published in March 2019, the BDI points out the important role of foreign investment in Germany in general and the positive role of China in particular (Mair et al. 2019) .

In the interviews conducted as part of the study, representatives of business and investment promotion

agencies in various federal states generally expressed a positive attitude towards Chinese investors, especially with regard to new settlements, but also in the case of takeovers or majority shareholdings. The investments of German companies in China are also considered positive by experts, although they point to improved but still unfair conditions (interviews 2019).

German-Chinese cooperation has great potential for both sides in the future, both for economic development in general and for the field of innovation in particular. The sale of high-tech products in China offers a large market for German companies. (McKinsey Global Institute 2015, p. 42) . At the same time, local companies can benefit and learn from China's rapid development in areas such as digitalisation and artificial intelligence. Synergies are of particular interest in these areas, as China has already made great strides and produced some innovative companies. In addition to their own engagement in China, direct linkages through Chinese participation in their own company are attractive for German or European companies and an opportunity for greater significance in the Chinese market.

China's industrialisation (1.0 to 3.0) - which is mentioned less frequently - and its increasing focus on high technology as part of the MIC 2025 strategy, holds great potential for the sale of high-quality German products (Ifo Institute 2018) .

"The ecosystem in China, consisting of state support, start-up infrastructure, university education and cost-efficient supply chain, is fuelling the rapid development of digital technologies and products. German and European companies operating in China can also use the support system for their own research and product development and benefit directly from high-tech subsidies or tax reductions." (Haug 2019, p. 43)

6.7.2 Challenges

China's economic development and growing capacities in high-tech sectors are creating new sales markets for European companies, but at the same time are leading to stronger global competition. Especially the industrial sectors in which Germany plays a central role are the focus of Chinese industrial policy. Now that Chinese companies are in a position to offer technologically sophisticated products at sometimes lower prices, German companies are threatened with the loss of market shares both in the Chinese and European markets as well as in third markets. In the long term, lower market shares can lead to lower profits and thus less funding for R&D. (Zenglein and Holzmann 2019) .

In this context, China's MIC 2025 strategy is also facing increasing international criticism, as it not only envisages the growth of China's high-tech sectors, but also explicitly aims to increase market share and squeeze out competitors. (Ifo Institute 2018) . For example, China's share of the national market for industrial robots is expected to reach 70 % by 2025, which would mean a significant reduction in the share of foreign companies. (Ifo Institute 2018) . In absolute terms, the general growth in China may nevertheless lead to positive effects for foreign companies.

Buying up foreign companies is one of several tools of MIC 2025 and support from the Chinese state in the form of concessional loans and administrative assistance can lead to distorted competition (Ifo Institute 2018) . The concern that state-backed buyouts of European high-tech companies are taking place on a larger scale needs to be addressed. Innovative European start-ups are attractive targets for China's big tech firms, while access to Chinese start-ups is made more difficult for Western firms. (Glatter 2017, p. 1; Jungbluth 2016, p. 35; Mair et al. 2019, p. 21) .

The unequal market access described above and the resulting lack of a level playing field continues to be a relevant disadvantage for European companies in China. This poses incalculable risks for companies and inhibits their ability to innovate. (Kunze and Windels 2018, p. 7) .

With regard to Europe, another danger is seen that is also highly relevant for Germany: individual states of the European Union could become too economically intertwined and dependent on China as a result of Chinese investments. China could gain political influence in this way. Since a large part of the decisions at the EU level must be made unanimously, it is possible that the blocking attitude of a single

country could limit the ability of the entire EU to act. (Loesekrug-Pietri 2019) . So far, however, the effects are still considered to be rather small. (Ferchen et al. 2018) .

Shifting R&D activities to China is attractive for German companies due to various incentives. Nevertheless, trade and investment restrictions continue to impede or prevent foreign investors from accessing the Chinese market. While Chinese firms enter a largely open market in Europe, European firms face restrictions in China (Bartsch and Laudien 2016, p. 11) . According to German stakeholders based in China, despite the new Foreign Investment Law and other small steps towards more attractive investment conditions, German companies are not expected to achieve a *level playing field* to European standards in the short or long term (interviews 2019). Chinese market conditions are subject to constant change, which foreign companies must adapt to.

6.7.3 Measures

There has been an intensive discussion in recent years on how to deal with Chinese FDI and fair framework conditions. On the one hand, there is a desire to better protect the European market and its companies, but on the other hand, there is also the opinion outlined above that Chinese FDI represents a significant opportunity for Germany and Europe.

A common European approach

One point mentioned in many studies and commentaries is the need for stronger cooperation within Europe. In view of China's growing influence, it is increasingly important that the individual European states coordinate with each other and pool their negotiating power. In the area of trade, the European Commission has negotiating authority and is developing the European Investment Screening Mechanism and a China-Europe trade agreement in this context. With a common EU voice, it is easier to argue for a level playing field for European and Chinese companies in the areas of investment and market access. Only at the European level is there the necessary clout to draw boundaries and threaten relevant consequences. (Zenglein and Holzmann 2019, p. 15) .

"Europe needs to better leverage the collective weight of EU member states. Larger member states like Germany and France need to take serious steps towards putting their privileged bilateral relations with China in the service of common European interests. Complaining about the 16+1 format China uses to interact with smaller EU members in Central and Eastern Europe while engaging in 1+1 formats with Beijing will not help to come up with a collective EU response on issues where Chinese action fails to resonate with shared European interests.“ (Benner et al. 2018, p. 7) .

Increasing China competence and active monitoring of Chinese investors

One problem that often arises in connection with Chinese investments is the lack of knowledge about the background and structure of Chinese trade or concrete Chinese investors (Ferchen et al. 2018, vii) . To answer the question of whether China is buying up European technology with state help, it is necessary to know what connections the investors have to the state, to what extent they are state-owned and whether they have preferential access to state financing. In questionable cases, it is even more important to have a solid knowledge base and trained staff to be able to consider evidence-based countermeasures (Interview 2019; d'Hooghe et al. 2018; Ferchen et al. 2018, vii). In addition, more knowledge about potential investors also leads to better economic outcomes for both sides. In some German states, potential Chinese companies are actively sought out as partners primarily from the Chinese SME sector, which fit well with German regional structures and technology priorities (Interview 2019). Experience and knowledge about China and its investors should be bundled and made available in a suitable form. In the sense of the European dimension mentioned above, this expertise should not only be available to Germany, but should also be open to other EU member states where appropriate.

On the one hand, this can be achieved by expanding Chinese language skills and China competencies in Germany. For broad and early promotion, it is recommended that Chinese be anchored as a regular

school subject and that modern China knowledge be taught in school subjects such as geography, politics, history and social sciences, as well as in upper school seminars and project weeks. (Stepan et al. 2018, pp. 9-10) . In addition to the political-administrative anchoring in the school curricula, this also requires the financing of teachers, teaching materials and teacher training by the Ministries of Education and Cultural Affairs. (Stepan et al. 2018, pp. 9-10) . At the university level, China competencies can be built up through offers such as double degree programmes, exchange programmes, training of administrative staff, etc. (Stepan et al. 2018, pp. 11-12) . In addition, "*European students [...]* should be *encouraged to study in China in order to advance existing collaborations and avoid knowledge gaps about China in the next generation of researchers"*. (d'Hooghe et al. 2018, p. 5) .

On the other hand, it is considered useful to attract and involve Chinese talents with German or European degrees and German alumni with experience in China. Their expertise on economic, historical and cultural linkages in China is conducive to the assessment of actors and motives of Chinese FDI and can strengthen the information base for political decisions. (Ferchen et al. 2018, vii) . Currently, the USA is the most popular destination for Chinese talent. Germany and Europe can benefit from the current poor climate between the two countries and the accompanying tightening of entry regulations by the US against Chinese talent by increasing their attractiveness as a destination for foreign professionals. (Zhang et al. 2019) . This could be achieved, for example, through faster visa procedures, lower requirements for permanent residency and naturalisation, bilateral agreements and training partnerships. (Bartsch and Laudien 2016, p. 11; Petino 2019, p. 6) . Chinese returnees who have studied or worked in Germany and China alumni from Germany can also play an important role, for example, in the context of FDI in both directions. (Veugelers 2017, p. 15; Müller-Jung 2019) . .

"European governments need to invest in high-calibre, independent China expertise. Raising awareness about and responding to China's political influencing efforts in Europe can only succeed if there is sufficient impartial expertise on China in think tanks, universities, NGOs, and media across Europe. This will also help to keep out 'unwanted' Chinese money in those institutions. " (Benner et al. 2018, p. 7)

EU Investment Screening Mechanism

In view of China's increased financial engagement in Europe, there have been calls in recent years for an investment screening mechanism at the European level with the aim of exchanging FDI information at the supranational level. In March 2019, the European Parliament and the European Council decided to establish the EU Investment Screening Mechanism. The mechanism should be fully operational by October 2020. (European Commission 2019b) . Similar mechanisms have already been introduced by most OECD countries and some of the EU countries themselves. Compared to the screening mechanisms of other countries, the requirements of the European mechanism are considered less strict. The EU mechanism is not intended to replace any national screening procedures, but aims above all at better exchange and cooperation between the individual member states. In the case of investments, the EU Commission only has the right to make recommendations that affect several member states or the EU as a whole. These recommendations are not binding on the states, but in the case of non-compliance, this must be explicitly justified. (Hanemann et al. 2019) .

Just under half of the EU states still have not established a corresponding instrument at the national level and will not be pushed to do so by the new mechanism. In this respect, the mechanism represents a compromise between, on the one hand, a stronger role for the EU as an overarching and coordinating body and, on the other hand, the control of the individual member states over their national FDI. (European Parliamentary Research Service 2019) .

According to the EU Investment Screening Mechanism, the focus of an investigation is first and foremost on investments that affect security and public order. Furthermore, it is examined to what extent the investor is state-financed or acts in accordance with a state-directed policy or instruction. This is often the case, especially in the case of Chinese investments. (Hanemann et al. 2019) .

In other countries, such as Canada, the tasks of the screening mechanism are broader, so that questions about the consequences for the economy and innovation in the country are also asked and included in the evaluation of an investment. There is also the idea of setting tighter barriers specifically for the digital economy in order to prevent the big foreign digital platforms from buying up emerging start-ups in the sector. (Shi-Kupfer and Ohlberg 2019) . However, such a broad-based mechanism for the EU would inevitably become a political instrument that would result in few clear boundaries and many individual discretionary cases. (Hanemann et al. 2019) .

The examples of Taiwan and Japan, which have significantly closer economic ties with China than Europe, show that stricter regulation of Chinese investments by no means leads to a fundamentally worse economic relationship. (Zenglein and Holzmann 2019, p. 14) . There, much stricter investment control regimes have already been introduced to prevent the sell-off of China's own high technology. In this way, China's investments in Japan and Taiwan have been limited to 1/35 and 1/26 respectively of those in the other direction. (Zenglein and Holzmann 2019, p. 14) .

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Appendix 1: List of interview partners

1) Interviews in Germany (25 interviews, May 7th - July 4th 2019)

German government agencies		
Hr. Dirk Hensel plus Kolleg*innen	Pressesprecher	BfDI-Bundesbeauftragten für den Datenschutz und die Informationstechnik Bonn
Hr. Prof. Dr. Dirk Lanzerath	Geschäftsführer	Deutsches Referenzzentrum für Ethik in den Biowissenschaften
German intermediaries in the private sector		
Hr. Andreas Damrau	Senior Manager Investor Services	HA Hessen Agentur GmbH Hessen Trade & Invest GmbH, Wiesbaden
Hr. Thomas Heck	Leiter der China Business Group	PwC | Partner, PricewaterhouseCoopers GmbH Wirtschaftsprüfungsgesellschaft, Frankfurt am Main
Hr. Thomas Horn	Geschäftsführer	Wirtschaftsförderung Sachsen GmbH, Dresden
Hr. Dr. Wolfgang Hübschle	Geschäftsführer	Invest in Bavaria - Die Ansiedlungsagentur des Freistaats Bayern, Bayerisches Staatsministerium für Wirtschaft, Landesentwicklung und Energie, München
Fr. Nina Lehfer	Projektmanagerin Länderbereich China & Start-ups Abteilung Außenwirtschaft und Standortmarketing Wirtschaft	BADEN-WÜRTTEMBERG INTERNATIONAL Gesellschaft für internationale wirtschaftliche und wissenschaftliche Zusammenarbeit mbH, Stuttgart
Hr. Dr. Qiang Fu, Fr. Bauer	Leiter Servicecenter Greater China	NRW.INVEST GmbH, Düsseldorf
Hr. Dr. Klaus-R. Sprung	Geschäftsführer	AiF Projekt GmbH, Berlin
Representatives of German/Chinese industry		
Hr. Dr. Christian Haug	Geschäftsführer	Startup Factory China GmbH, München
Hr. Thomas Heck	Leiter der China Business Group	PwC | Partner, PricewaterhouseCoopers GmbH Wirtschaftsprüfungsgesellschaft, Frankfurt am Main
German intermediaries in research		
Fr. Dr. Irene Huber	Forschungszentrum für Gesundheitswissenschaften (703), Geschäftsführerin	Universität Hohenheim
Hr. Dr. Eckart Bierdümpel	Head Multinational Networking, Secretary General WAITRO	Fraunhofer-Gesellschaft, Schloss Birlinghoven, Sankt Augustin
Fr. Marijke Wahlers	Bereichsleiterin Internationale	Hochschulrektorenkonferenz

	Angelegenheiten	HRK
Fr. Dr. Nicole Saverschek	TU9-Geschäftsführerin	TU9 German Universities of Technology e.V.
German university representatives for Asian Studies/Sinology/China Competence		
Hr. Prof. Dr. Björn Alpermann	Lehrstuhlinhaber für Contemporary Chinese Studies	Universität Würzburg
Hr. Prof. Dr. Sebastian Bersick	Lehrstuhlinhaber, Internationale Politische Ökonomie Ostasiens	Fakultät für Ostasienwissenschaften, Ruhr-Universität Bochum
Fr. Prof. Dr.-lng. MENG Liqiu	Lehrstuhl für Kartographie, stv. Vorsitzende Senat DLR	TU München
Fr. Prof. Dr. Dr. Nele Noessel	Inhaberin des Lehrstuhls für Politikwissenschaft mit dem Schwerpunkt China/Ostasien	Universität Duisburg-Essen
German representatives of alumni projects		
Fr. Dr. Sigrun Abels	Alumni-Projekt	TU Berlin
Hr. Prof. Dr. Kurt Fritzsche	Alumni-Projekt ; Psychologie/Psychiatrie	Uniklinik Freiburg
German university representatives for research		
Hr. Dr. YAO Gang	BMBF-Projekt Watch, RWTH Forschungskoordinator zwischen Deutschland und China, Projektleiter	RWTH Aachen
Hr. Prof. Dr. Grün	BMBF-Projekt FPC@SJTU - Fraunhofer-Projektzentrum für gebaute Umwelt an der Shanghai Jiao Tong Universität, Projektleiter	Fraunhofer-Institut für Bauphysik IBP
Hr. Prof. Dr.-Ing. Stephan Köster	BMBF-Projekt Universität Leibniz- Tsinghua University Platform for United Water Science & Technology Innovations (PLUS), Projektleiter	Institut für Siedlungswasserwirtschaft und Abfalltechnik, Leibniz Universität Hannover
Fr. Dr. Annett Lang	Leitung International Office	Universität Bremen

2) Interviews in China (22 interviews, June 18 - July 12, 2019)

German and European actors in China (including private industry)		
Hr. Dr. Oliver Prüfer	Deputy General Manager	German Industry and Commerce Greater China, Beijing
Hr. Christian Engels	Geschäftsführer	German Industry & Commerce Greater China | Guangzhou
Hr. Jelte Wingender	Corporate innovation, Senior manager	Inno Way
Hr. Stephan Gätzner	Chief Representative	BDI-Vertretung Peking
Hr. Dr.-Ing. Tobias Arndt	General Manager	GAMI Global Advanced Manufacturing Institute, Karls-ruhe Institute of Technology KIT
Hr. Philipp Agathonos	Director, Office of Science and Technology Austria	Österreichische Botschaft Peking
Hr. Jens Hofmann	Wissenschaftsreferent	Deutsche Botschaft Peking
Hr. LUAN Tian	Director	Global Incubator
Hr. Halldor Berg	Country Representative, Support	EURAXESS China

Hardarson, Fr. LI Yuhui	Officer	
Researchers in China		
Hr. Prof. Andy Hor	Vice President und Pro-Vice-Chancellor (Research)	University of Hongkong
Hr. Dr. Ralf Jauch	Principle Investigator	School of Biomedical Sciences, University of Hong Kong
Teilnehmende des EURAXESS Fokus-Gruppen-Gesprächs: Hr. Juan Bojaca Fr. Marie-Luce Chevalier Hr. Julian Koellermeier Hr. Jose Pastor Fr. Veronique Prinet Hr. Karlis Rokpelnis Hr. Francesco Silvestri Fr. Helene Uhde Hr. William Vega Fr. Sjoukje Wu		APCG Chinese Academy of Geological Sciences Peking Universität Tsinghua Universität Chinese Academy of Sciences Council on International Educational Exchange (CIEE) Beijing Foreign Studies University/ Association of Italian Scholars in China (AAIIC) Beijing Institute of Technology VEGA SALAS S.A.C. Chinese Academy of Sciences - Sino Danish Center
Chinese promoters		
Hr. LIU Hui	Department for Policy Evaluation	National Center for Science and Technology Evaluation (NCSTE)
Hr. XIE Min	Director of National Center for Science and Technology Evaluation	NCSTE
Fr. YAN Dong	Director of Department for Innovation Policy Evaluation	NCSTE
Hr. LI Zhe, Hr. LI Yan u. weitere Mitarbeiter	Institutsleiter, Wissenschaftliche Mitarbeiter	Chinese Academy of Science and Technology for Development (CASTED)
Fr. SONG Song	Wissenschaftliche Mitarbeiterin	China Science and Technology Exchange Center (CSTEC)
Hr. ZHANG Chunpeng		NCSTE
Fr. Xu Heng, Hr. SU Liang und 7 weitere Mitarbeiter (Gruppendiskussion)	Senior Manager und Researcher	Guangdong Techno-Economy Development Centre (unter Guangdong Ministry of Science and Technology)
Science Parks in China		
Diverse Senior Manager und Mitarbeiter der Parkverwaltung	Senior Manager und Mitarbeiter	Bio-Island
Hr. HE Wen, Hr. CHEN Shichang und weitere Senior Managers	Vice President, Senior Manager	Tianan Cyber Park

Hr. ZHOU Teng	Senior Manager	Z-Science Park