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China's Development of an Innovation-driven Economy - An Intermediate Assessment

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Abstract

China's economic, technological and scientific achievements of the past years and decades are impressive. However, the country's policy makers have even higher aspirations and therefore set up a number of policies to tackle the threat of the so-called middle-income-trap. This paper describes and discusses some of these policies, of which the Innovation-Driven Economy Development Strategy is seen as the backbone of current Chinese STI policy. The level of achievements as well as the expected developments isare put into perspective by selected empirical data. We conclude that China's industry will further improve its competitiveness in several sectors in the coming years. Western representatives need to wave good-bye to the ideas that China assimilates. At the same time, the era of the "land of gold" that when China provides the world with low-cost products and buys high-tech goods from Western companies is over. However, if China intends to become a reputable member of the international STI community, the country should develop actively the nowadays often-demanded 'level-playing field'. This would not only mean that China needs to accept and implement internationally agreed rules and institutions. It would also mean vice versa that Westerners accept the differences in the systems, the Chinese Way as well as the Chinese 'market economy', which is not meant to be the same like in Europe or North America.

Keywords

innovation-driven; China's development; intermediate assessment

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1. Introduction

China's economy has achieved much since Deng Xiaoping's opening up policies started in 1977 and the introduction of the 'Four Modernizations' – agriculture, industry, defence as well as science and technology – which paved the way for further changes like private property, intellectual property and other economic reforms. The growth rates of almost all indicators are impressive and China reached a level in most dimensions like R&D personnel, the size of the economy or the number of national patent applications that put it among the top-3 countries in the world (Huang *et al.*, 2016) – and even more can be expected, given its size and its ambitions.

One of the cornerstones in the process of economic catch-up and development was China's WTO accession in 2001. This gave another boost to the Chinese development, especially, in the first half of the last decade, mainly based on the activities of foreign companies and their foreign direct investment[1]. It initiated a fast growth of the national market in a very short period. One indication of the foreign drive of this fast growth was, for example, that the patent applications by foreign companies were much higher than by national applicants in the early years of the last decade. Since about the years 2007/2008, however, national applicants filed more patents in China than foreign applicants (Frietsch and Wang, 2009). Collaboration in patent applications between foreign firms and Chinese inventors is still at a very low level (Preziosi *et al*., 2019).

Another milestone was the formulation of the National Medium- and Long-Term Programme for Science and Technology Development (MLP) in 2006 that defined the overall development goals in S&T until the year 2020 (Cao *et al*., 2006). Most of the science and innovation policies that we see today are a continuation or an implementation of the aims set in 2006. The MLP defined, for example, the R&D intensity (share of GDP spent on R&D) goals of 2% in 2010 and 2.5% in 2020 as well as the aim of strengthening "indigenous innovations" (Gu *et al*., 2016), being defined as innovations with considerable Chinese intellectual input and creating Chinese added value.

The term "indigenous innovation" and anything that is connected to it was heavily criticised as techno-nationalism (Suttmeier, 2005). Especially the USA government was constantly repeating this criticism (Koleski and Salidjanova, 2018), but also many scholars were taking up this line of argumentation (Wilsdon, 2007; Nakayama, 2012; Cunha, 2015; Suttmeier, 2014). Possibly, in consequence, the term "indigenous innovation" was hardly used any more in the second half of the last decade, but – so the argumentation in this chapter goes – the underlying policy was never given up. The rhetoric of Ppresident and Party Secretary Xi Jinping even continues and intensifies these policies, for example, in his 'Chinese Dream' – a general vision of China's role in the world and a claim of its supposed 'natural' position in it. In addition, policies like Made in China 2025 also set clear national goals for ownership of technologies, production values or creation of added value, which some scholars interpret as techno-nationalism and the intention of crowding out foreign companies.

These policies and policy goals were – and still are – the foundation of the Chinese aim to shift the national economy towards an innovation-driven economy and to become more independent of technology imports.

[1] https://data.oecd.org/fdi/fdi-flows.htm

Next to the MLP and the 'Chinese Dream' that set the framework for policy making in many areas, the outline of the National Innovation-Driven Development Strategy (2016) is one of the core strategies that shape the current science, technology and innovation (STI) policies. In this paper, we will argue that this policy is in fact the most important policy strategy in China, embedded in the long-term ambition currently articulated as the "Chinese Dream". In our view, both the hotly debated industrial strategy "Made in China 2025" as well as aspects of the "Belt and Road Initiative" serve the overall aim of Innovation-Driven Development - and can only be fully understood, when seen in this context.

2. New Topics and Long-Term Goals: the Innovation-driven Economy Development Strategy

Beyond its primary ambition to establish a world-class science system, much of the last decade's science and innovation policy in China has been dedicated to supporting the upgrading of industry and to addressing societal problems. If anything, this second dimension has recently become more important with Xi Jinping's calls on science to "serve the country". With a view to innovation, the overarching ambition of many policies has been to overcome the so-called middle-income-trap, *i.e.*, move away from low-cost, assembly-oriented production to a more balanced economic structure that generates higher value added within the country. For Chinese policy makers, one of the core challenges is to become less dependent on foreign markets and especially on technology imports in crucial sectors. President Xi Jinping pointed this out: "China's foundation for science and technology innovation is still not firm. China's capacity for indigenous innovation, and especially original innovation, is still weak. Fundamentally, the fact that we are controlled by others in critical fields and key technologies has not changed" (European Chamber 2017: 7).

While the 'National Medium- and Long-Term Programme for Science and Technology Development' (MLP) that was published in 2006 as well as the 12th Five-Year-Plan (12th FYP) already addressed the innovation orientation and the upgrade of the economy, it was made explicit in the National Innovation-driven Strategy in 2012 and its outline, published in 2016. This strategy conveys three main steps for the further development of the country that were then adopted as strategic goals for achieving a 'socialist modernization' by the 19th National Congress of the Communist Party of China in October 2017. As it pledges, by 2020 China will be an innovative nation, an international innovation leader by 2030, and a world powerhouse of scientific and technological innovation by 2050[2].

The shift from a low-cost to an innovation-driven economy as formulated in the National Development Strategy is the overarching approach. It was explicitly stressed in the 13th FYP and several measures and policies were put into the planning to support this goal, among them Made in China 2025 (from now on called MIC2025) or Internet Plus, but also the reform of the science system, the focus on mass entrepreneurship and mass innovation as well as additional R&D investments. Elements of an innovation-driven economy are talents, enhancing innovation capabilities, an adequate entrepreneurial ecosystem, or general improvements of the innovation system as such (Jung, 2016). Quantitative targets like the 2.5% goal of R&D expenditures over GDP that were already defined in the MLP in 2006 were emphasised again.

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[2] http://english.gov.cn/policies/latest_releases/2016/05/20/content_281475353682191.htm

A change towards a consumption-oriented economy and a development of the local market, thereby becoming more independent of exports and global markets, is also stressed in the strategy[3].

Individual policies, like MIC2025 or the Internet Plus strategy are contributing to this overall goal. Individual fields and technologies should also contribute. "Make breakthroughs in key technologies and equipment, such as additive manufacturing, smart sensing and control … [as well as] breakthroughs in a range of key equipments which are subject to export restrictions abroad and urgently needed domestically, such as aero-engines, gas turbines and high-end CNC machine tools"[4]. In addition, the strategic industries, firstly mentioned in connection with the release of the 12th FYP in the year 2011 and updated in 2017, still play a major role also for the general economic upgrade. The list of these industries covers energy efficient and environmental technologies, next generation information technology, biotechnology, high-end equipment manufacturing, new energy, new materials, and new-energy vehicles (NEVs). In the year 2017, two more industries were added, namely digital innovation and related services.

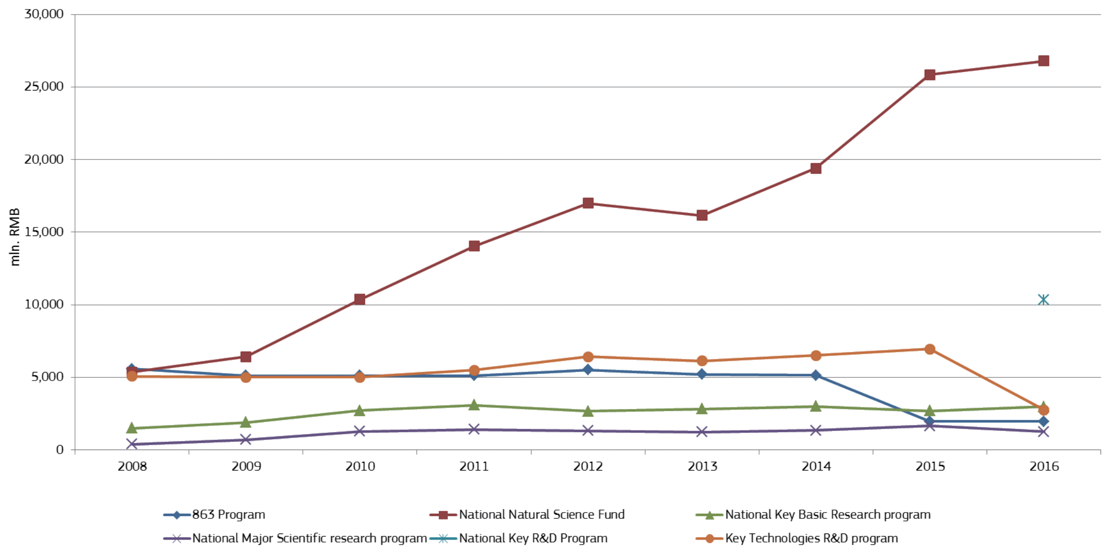

Fig. 1 Budget of key funding programs in mln RMB

Source: National Bureau of Statistics (2017)

Additional focal points of research that were announced in the second half of 2017 are quantum research, 5G, and artificial intelligence (AI)[5], including autonomous driving[6]. Furthermore, basic research is strengthened by restructuring the funding system and the seven-fold increase of the budget of the National Natural Science Foundation of China (NSFC) between 2008 and 2015 (see Fig. 1). Technology

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[3] https://www.rieti.go.jp/en/events/bbl/13041201.html

[4] http://english.cd-smartindustry.com/news_show.aspx?id=245 Unavailable

[5] http://www.gov.cn/zhengce/content/2017-07/20/content_5211996.htm; http://www.usito.org/news/china-launches-implementation-national-ai-development-plan

[6] http://www.usito.org/news/ndrc-releases-intelligent-vehicle-innovation-and-development-strategy; http://www.ndrc.gov.cn/yjzq/201801/t20180105_873146.html

transfer and collaboration between science and industry is still a challenge in China. The State Council had already identified this several years ago and released a notice, which drafts a plan to set up a national technology transfer system in two steps. By 2020 a first professionalization of institutions and people is foreseen and by 2025 the transfer system should be in full operation[7].

3. Investments Laying the Foundation

Overall, recent investments in science and technology document the government's strong commitment towards upgrading both science system and innovation-capacities in the economy. A current national R&D intensity, *i.e.* share of R&D expenditures per GDP, of more than 2% documents the Chinese government's strong commitment to invest substantial resources. Leaving all other 'BRICS economies' far behind at levels around 1%, China has recently surpassed the EU-28 in terms of R&D intensity and thus stayed in line with the ambitions spelt out in the MLP or the goals put forward in the 12th FYP (2011-2015) (Huang *et al.*, 2016).

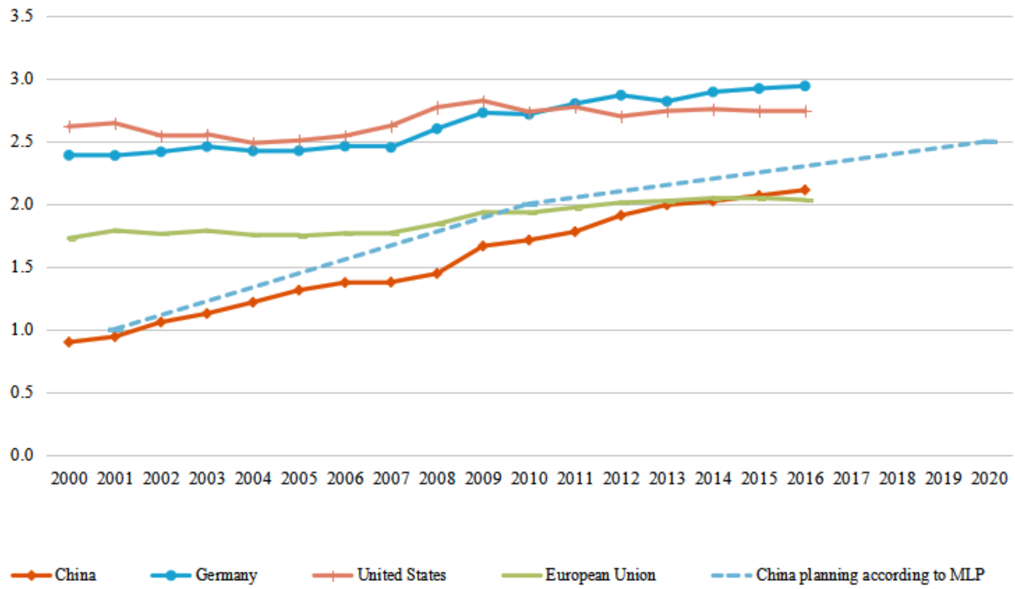

Fig. 2 R&D-intensity (total R&D expenditures as a share of GDP) for China and selected regions/countries (2001-2016)
Note: Data for China in 2016, Germany 2015 and 2016, United States 2015 and 2016 stem from OECD – MSTI; data for the European Union 2016 stem from Eurostat - rd_e_gerdtot.
Source: Worldbank – WDI; Eurostat – rd_e_gerdtot; OECD – MSTI.

According to Chinese official statistics, about 77% of these gross domestic expenditures on R&D are spent by industry and 23% by government research organisations and universities, respectively. Only few countries like Japan or South Korea reach such high shares of industrial R&D expenditures by industry, while even in the USA or Germany this share is much lower. Even though business R&D

[7] http://www.usito.org/news/china-establish-national-technology-transfer-system

in China includes efforts by state- owned enterprises, the statistics provide no direct evidence that their activities were primarily financed by the state. According to the S&T Statistical Yearbooks (NBS, MOST 2017) almost 95% of business sector R&D isare funded by self-raised funds, only about 4% by government and less than 1% from abroad. Even in the US, only 88% of business sector R&D isare financed by self-raised funds, in the EU-28 this applies to 82%. In Russia, to the contrary, only 34% of current industrial R&D activities are privately funded. So are Chinese data wrong or even fake?

The answers are yes and no. No, because the statistics formally follow the definition also used by OECD or Eurostat. Indeed, the Chinese government does not commonly finance R&D in companies directly. Moreover, there is anecdotal evidence that, up until today, notable shares of direct R&D funding seem to be distributed based on personal networks (*guanxi*) and thus do not reach the industrial sector very broadly (Wang *et al*., 2017). Over the past decades the Chinese National Bureau of Statistics has improved the reliability and international comparability of the data it collects. Since local statistical offices are reliant for their funding and staff on local governments there can be scope for undue political influence on the reporting of statistics at this level. "The NBS has been working hard to ensure that these types of local distortions do not occur with any frequency." (Simon and Cao, 2012). The importance given to reliable statistics has also increasingly been recognised and enshrined in Chinese law, which has strengthened the hands of the NBS in ensuring the reliable collection of statistics: *"Under the 2009 revised Statistics Law, government officials and institutional leaders who make purposeful changes or falsify statistics, ask statistical agencies to fake data or take revenge on staff who refuse to commit such acts will be punished and those fabricating data to gain honors, material rewards or promotions will receive legal punishment if convicted"* (Simon and Cao, 2012).

Yes, because the statistics are wrong or at least misleading for two reasons. First, China offers considerable tax reductions to so-called high-tech firms, defined by their share of R&D expenditures per turnover. Non-surprisingly, firms tend to claim this status by reporting more R&D expenditures than they really have. Second, most companies around the world fund their R&D by cash flow (Schubert and Rammer, 2016) as it is simply too risky to incur debts for an uncertain endeavour like R&D. Chinese state-owned companies, to the contrary, receive considerable loans at favourable conditions which, in some cases, do not even have to be paid back. While this loan funding is formally "selfraised", it is effectively an expression of state support for specific aspects of the economic process. Even in case such loans are not used for R&D directly, they free other resources, which can then be invested in R&D.

4. Substantial Advances in Several Dimensions

4.1. The performance of the science system

The higher echelons of the Chinese science system are built around a few top research universities – the group of the so-called C9 – and a number of relevant and influential academies, namely the Chinese Academy of Sciences (CAS), the Chinese Academy of Social Sciences (CASS), and the Chinese Academy of Engineering (CAE). While the CAE is solely an advisory body, the CAS is both an advisory body of elite scientists and a ministerial level agency in charge of the management of a network of research institutes covering most fields of natural science. Beyond these organisations, a large numbers of second- and third-tier universities exist as well as research organisations on the national, provincial and even

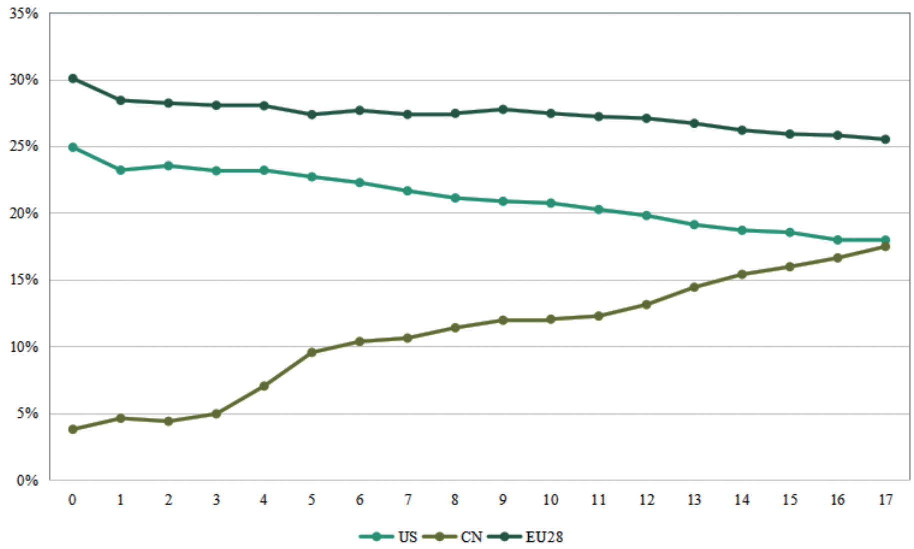

Fig. 3 Shares of journal publications in the Scopus database (2005-2017)

Note: We use fractional counting by countries here. Each paper is assigned to a country according to the share of distinct author affiliations mentioned in the paper. The numbers on the horizontal axis represent the year, e.g., the number "1" indicates "2001".

Source: Elsevier – Scopus; Frietsch *et al*. (2019)

the municipal level. Through the 211 and especially 985 programmes the Chinese government invested heavily in the development of research universities (Zhang, Patton and Kenney, 2013). In 2017, these programmes were replaced by the Double First Class Programme which aims to bring 5 universities in the world's top 20 and an additional 16 in the world's top 50 by 2050 (Wang, 2017). All of these organisations have considerably increased their scientific output and tried to catch -up with national and international organisations in terms of quality of outputs and scientific merits.

One indication of China's increasing scientific capabilities is its scientists' rising number of publications in scientific journals. So far, most of them are in Chinese and therefore often invisible to international communities. In the year 2017, however, Chinese authors also published more than 380,000[8] journal articles listed in the Scopus database, *i.e.* publications in international journals with peer review processes. Since 2005, the average annual growth rate (CAGR) of such publications has been about 9.4%, whereas the global increase in this period was just 4%. Even though most of the industrialised countries have also increased their publication numbers, they have been outperformed in terms of growth rates by China – and by other BRICS – and therefore the shares of global scientific output have decreased for most of these countries, while it increased for China as well as India, Brazil or South Africa. China is meanwhile the third largest scientific research area, behind the EU-28 and the USA.

[8] This is based on the fractional counting methods, which means that a paper is fractionally assigned to the countries of authors mentioned on publication. For example, two Chinese and one European authors co-publish a paper, accordingly, this would count 2/3 for China and 1/3 for Europe. The sum of publications of all countries is therefore equal to the total of all publications in the database.

Next to this impressive increase of the total output, also the quality of these papers in terms of citations increased – on average. While in 2005 Chinese publications received 0.4 citations (field-specific) on average, the indicator values doubled until 2012 to 0.8 – this means on average a Chinese publication receives 20% less citations than the world average – and further increased to a value close to the world average of 1.0 in the year 2015[9]. In individual disciplines China had already reached a level even beyond the world average, for example in plant molecular life sciences (Jonkers, 2010), in materials research (Frietsch *et al*., 2008) or in genetics (Frietsch and Yu, 2010), just to name a few.

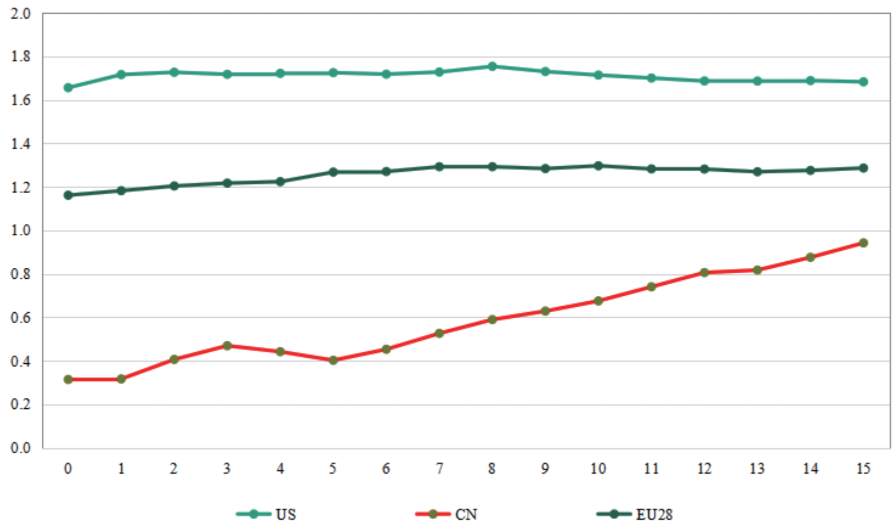

Fig. 4 Average citation rate (field specific)

Note: We use fractional counting by countries here. Each paper is assigned to a country according to the share of distinct author affiliations mentioned in the paper. The numbers on the horizontal axis represent the year, *e.g.*, the number "1" indicates "2001".

Source: Elsevier – Scopus; Frietsch *et al*. (2019).

Also concerning the Excellence Rate – this is the share of a country's publications that belongs to the 10% most highly cited papers in the world – China has been able to considerably increase its performance and is nowadays close to the world average (Frietsch *et al*., 2016). In sum, next to absolute publication output, China has been able to catch up with most industrialised countries also in terms of citations, respectively the quality of its research output.

The science system, one could conclude at this point, is in good shape and performs rather well. While there still is a focus on quantity instead of quality, the recent and ongoing reforms try to tackle this minus point. China has managed not only to increase its output in absolute terms, but at the same time also its quality and visibility, meanwhile reaching citation rates that are close to the world average. In some areas today, China already conducts excellent research, for example in materials research, nanotechnology, super-computing and genetics (Frietsch *et al*., 2008). China's scientific specialisation differs markedly from that of the US and EU. In science, China is more strongly

[9] A three-year citation window is applied here, which means that any citation in the publication year and the subsequent two years is taken into account.

specialised in computer science, chemistry, physics, engineering and materials science. The US and EU have a more balanced scientific portfolio including a relatively stronger specialisation in *e.g*. the social sciences and life sciences (Preziosi *et al*., 2019)

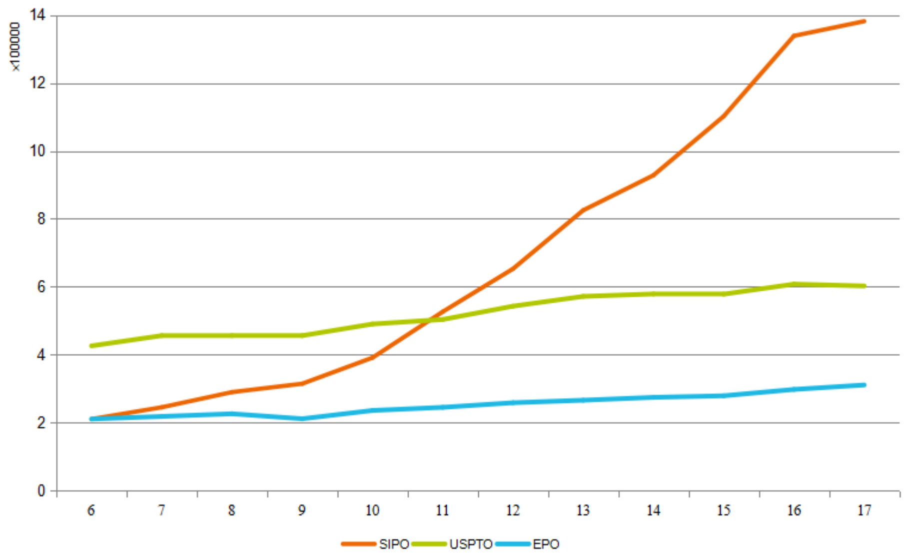

Fig. 5 Number of patent applications at three patent offices

Note: The numbers on the horizontal axis represent the year, e.g., the number "6" indicates "2006".

Source: Annual reports and statistics by SIPO, USPTO and EPO; own compilation

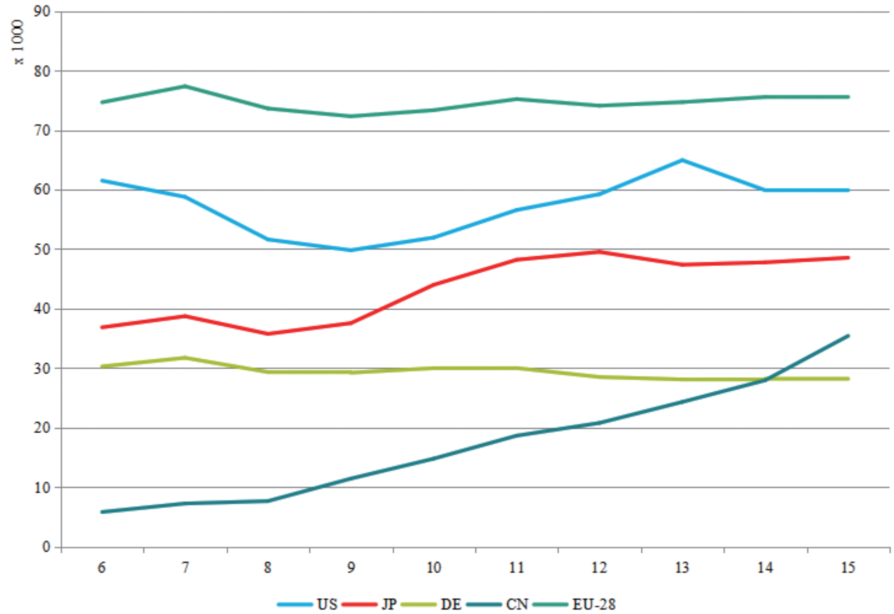

Fig. 6 Transnational patent applications by selected countries

Note: The numbers on the horizontal axis represent the year, e.g., the number "6" indicates "2006".

Source: EPO – PATSTAT; own compilation based on Neuhäusler *et al*. (2018).

4.2. China's technological performance

With a view to technological outputs, the achievements of the Chinese innovation system remain less clear. At the national market in China, competitiveness seems to exist in many sectors - in some of them with the help of government regulations - whereas at an international level, technological competitiveness remains focused almost exclusively on information and communication technologies (ICT).

China's increasing technological strength in the national market manifests itself in huge numbers of domestic patent applications. In 2017, the National Intellectual Property Administration (formerly known as State Intellectual Property Office, SIPO) now under the State Administration for Market Regulation received almost 1.4 million applications of invention patents[10]. In comparison, the United States Patent and Trademark Office (USPTO) receives only about 600,000 of such patents per year and the European Patent Office (EPO) about 300,000. The high numbers as such are the consequence of a quantity-oriented policy combined with the quest for economic success.

China's patent output targeting international markets - this includes PCT applications as well as direct filings at the EPO - has been growing at an annual average rate of 22.3% between 2006, when the MLP was published and therefore the first S&T strategy was formulated, and 2015[11]. In comparison, the patent applications by the EU-28 countries have been growing by 0.1% per year in this period and for the USA, for example, they have been decreasing by 0.3% on average.

With a number of about 35,000 transnational[12] applications, China has surpassed Germany (already in 2014) and applies for three times more patents than, for example, France or the United Kingdom. Taken together, EU-28 countries were responsible for about 75,000 patents in 2015, the USA for about 60,000 and Japan for about 49,000. So China is meanwhile the fourth largest country/region in the world in terms of transnational patents. It covers a share of 13.6% of all transnational patent filings, while Japan reaches a share of 18.6%, the USA of 23% and EU-28 a share of 29%[13].

4.3. Trade data as indications of economic competitiveness

International trade is a signal of the attractiveness of goods and services provided by a country. At international markets, companies meet their competitors at rather equal conditions. In consequence, export performance is commonly considered as reflecting a country's competitiveness globally as well as in certain technologies/sectors.

As an export-oriented country with high shares of global exports and a considerable integration into international value chains, China was hit substantially by the Financial Crisis in 2007-2009. For example, Chinese exports decreased by 16% in 2009 compared to 2008 after growth rates of more than 30% in previous years[14]. In consequence, the Chinese State Council – like many other national government – released an economic stimulus package to support the national economy mainly by

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[10] http://english.sipo.gov.cn/statistics/2017s/201712/1111449.htm

[11] Patents are assigned to countries according to the inventor addresses. The data provided here is based on fractional counting, which means that each patent is split between countries based on the shares of distinct inventor countries. The sum across all fractionally counted patents for each country is equal to the total number of patent applications at the transnational level.

[12] Transnational patent applications are defined as patent families with at least a PCT or an EPO family member (Frietsch and Schmoch, 2010).

[13] According to WIPO statistics, China is meanwhile the second largest applicant country of PCT filings after the USA and ahead of Japan and Germany (see http://www.wipo.int/pressroom/en/articles/2018/article_0002.html).

[14] Own calculations based on UN – COMTRADE; exports are in current prices.

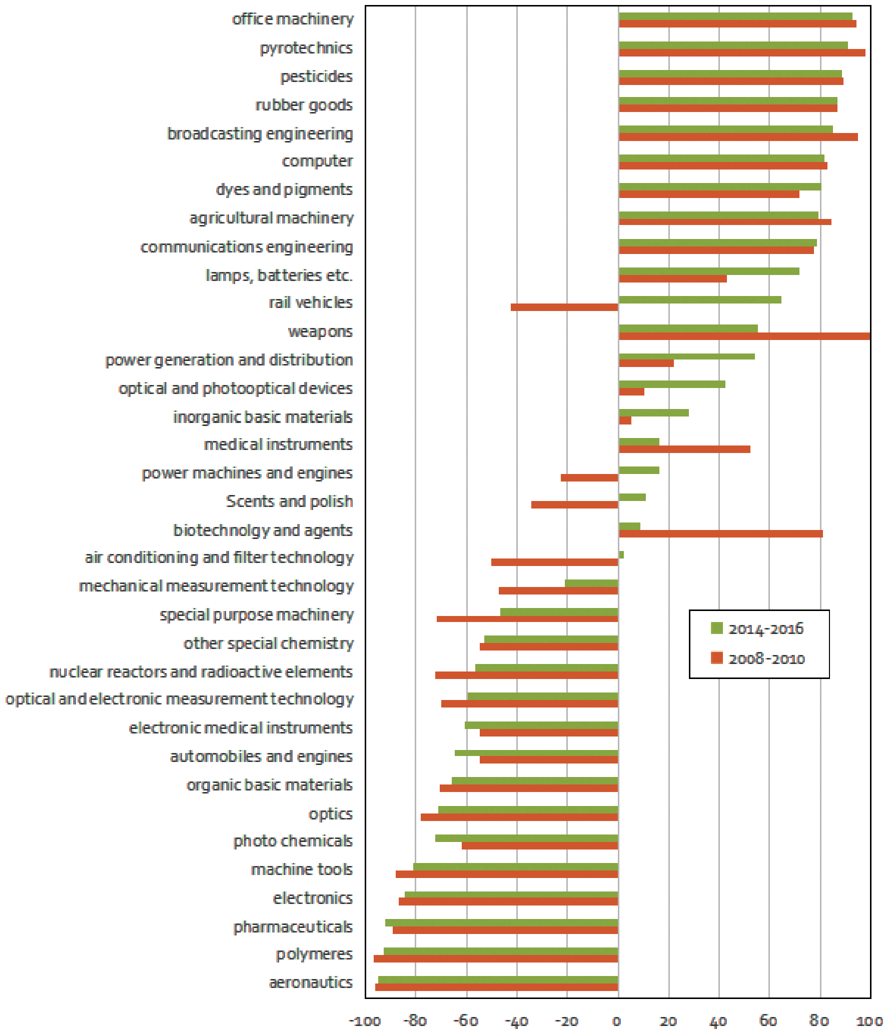

Fig. 7 Revealed comparative advantage (export-import-relation) for China (2008-2010 versus 2014-2016)
Source: UN - COMTRADE; own compilation.

infrastructure investments. Furthermore, they formulated the intention to become less dependent on international markets and to develop the national demand instead.

Since that period, China has, according to World Bank data, indeed been able to reduce the exports of goods and services as a share of GDP from about 35% in 2007 to about 20% in 2017. During the same period, the EU-28 countries have increased their shares from 38% to 45%. The USA reached a level of about 12%, which is rather stable.

Between 2008-2010, when the economic stimulus package was released, and the period 2014-2016, China's Revealed Comparative Advantage (RCA), an indicator that reflects how national industry prevails over foreign competitors at the national market, developed positively in many sectors of Chinese industry, including relevant sections of chemical products, mechanical engineering fields like power machines, special purpose machinery and especially rail vehicles (see Fig. 7). This illustrates how Chinese firms – including foreign-owned companies producing in China – became more competitive at the national market in most areas. Partially, this is due to regulations and framework conditions set by the Chinese government, which massively intervenes in some sectors. In some of these sectors the increase in domestic competitiveness could only be achieved because of such interventions.

While remaining the largest exporter of processed as well as high-tech goods in the world with increasing overall shares in world trade, China thus managed to develop its national market and to become domestically more independent of international markets and exports in different ways.

Based on an analysis of WIOD data, Preziosi *et al*. (2019) shows that China is becoming increasingly competitive in Global Value Chains. Between 2000 and 2014 China's share in manufacturing Global Value Chains increased by almost 14 percentage points. In the same period the EU's share decreased by 11 percentage points. They argue that this increasing share is mainly due to China's increasing competitiveness. What is more, the relative increase in this share is particularly strong in medium high-tech and high-tech sectors.

4.4. Global market development: a complementary strategy

Not least in view of the above mentioned improving position of China on global technology markets, Ppresident and Chairman Xi Jinping announced the Belt and Road Initiative (BRI) in 2013 as a new vehicle to establish China as a global trading nation. Conventionally, this initiative is

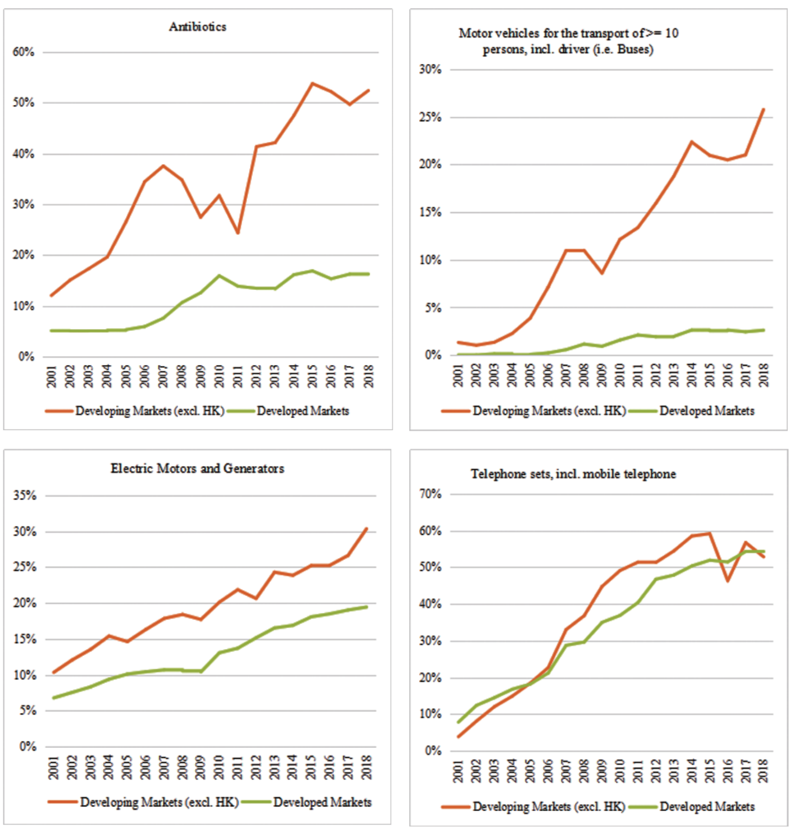

Fig. 8 Share of Chinese products in all imports (examples)

Source: own compilation based on UN – COMTRADE.

interpreted from three main angles. First, as an attempt to control resources and to ensure favorable terms of trade. Second, as a geopolitical repositioning and projection of Chinese power along major trade routes. And third, as a way to create additional investment opportunities for domestic firms at a time when the national market was saturated. While all this is most likely accurate, it is only one part of the picture and conceals China's foreign trade and investments' increasingly relevant role in shaping global markets and - with them - practices and standards of innovation.

Beyond key target areas of China's concerted standardization strategy, such as 5G, a second dimension remains too often disregarded. In practice, standards are set by the dominant offer on the market. Spare parts for Volkswagen will be more difficult to get hold of in France than in Germany while, in the latter country, car drivers will more easily find a Renault trader of which there are few in the U.S. In recent years, China has increasingly begun to use this mechanism to its advantage, by exporting its mid- and increasingly high-tech products to developing and emerging economies, where they replace European or American offers. Quite openly, it is one of the core ambitions of the BRI to open new markets for Chinese merchandise. Since China's merchandise goes notably beyond lowtech solutions, an increased opening of emerging and third-world markets for Chinese products came to mean that Chinese technologies became prevalent - and hence standard-setting solutions on various markets. As Chinese brands gain international recognition, Western products have been close to entirely replaced by Chinese offers in several third world markets.

Fig. 8 provides examples of specific goods in which China has earned a strong or even dominant market position in developing economies, including antibiotics, buses and self-propelled rail vehicles (*e.g.* high-speed trains) and could, as a tendency be extended by lorries, motorcycles, bicycles - but also medical and surgical appliances or laser-based machine tools. In addition, Fig. 8 illustrates cases in which Chinese products have become relevant on both developed and developing markets including two areas of relevant engineering goods: (less advanced) machine tools and motors, generators and their composite parts. In short, our evidence backs the assumption that Chinese products have become standard - and with this potentially standard setting - on various markets. Since the 2000s, various former markets for medium- to moderately high-tech products from Western companies have been successfully replaced by Chinese offerings in a systematic manner.

5. Remaining Challenges

China's investment in building up a national innovation system wasere massive. However, it was very input (*e.g.* R&D expenditures) or throughput (publications, patents) oriented with limited successes on the output side (Frietsch *et al*., 2015). What has been criticised in the past years by Chinese policy makers and economists alike was the inefficiency of the R&D system and the lack of quality of the output (Huang, 2016; Cao *et al*., 2013). In 2016, Premier Li Keqiang demanded the increase of the quality of the products of Chinese enterprises, especially of state- owned enterprises, while he called for more 'craftsmanship' in the production. In consequence, for the coming years the Chinese leaders announced[15] a quality initiative that will not only address issues in industry, but also in the

[15] See 19th Party Congress in October 2017: http://www.xinhuanet.com/english/special/19cpcnc/index.htm

science system. Institutional and organisational reforms - for example of the funding system, the CAS or also market liberalisations like removing the joint venture force *e.g.* in the automobile industry - will support this, but one can also expect that there will be strong monetary incentives as well as clear and high aims set by the forthcoming plans. The implementation of the quality strategy, however,

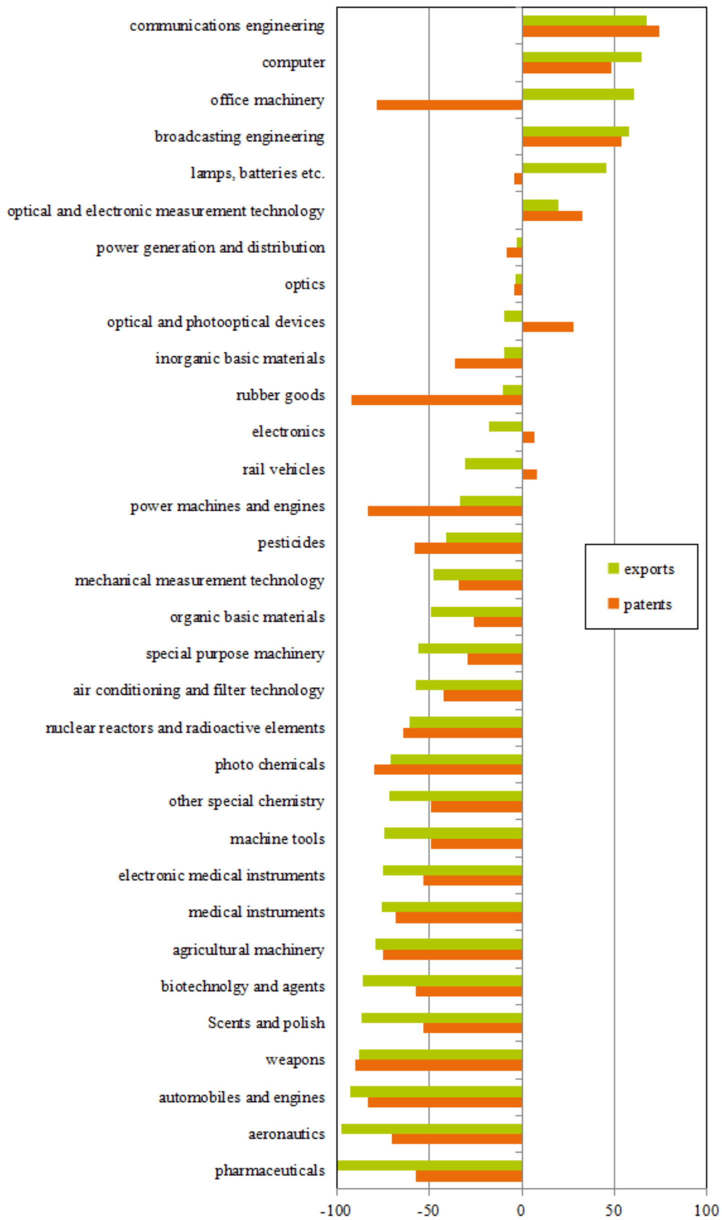

Fig. 9 Patent and export specialisation index for China

Note: The index is calculated as the share of a country'sies exports/patents in a particular field in relation to the worldwide share of that field. After transformation, zero indicates world average while positive/negative index values indicate shares above/below the worldwide average.

Source: EPO – PATSTAT; UN – COMTRADE; patents: 2013-2015; exports: 2014-2016; own compilation based on Neuhäusler *et al*. (2018).

still needs to be drafted in detail. In earlier years, most policies supporting the effort to increase the scientific output had the primary aim of increasing absolute numbers (Gao, 2009; Gao ,2010; Li, 2015; Ma, 2016; Qi, 2017; Wu and Hu, 2014) – a quantity-oriented strategy. In recent years, there have been some rather quality-oriented support measures. Even more are to be expected in the future.

Overall, several findings underscore a set of important, remaining challenges on China's way towards a truly innovation- driven economy:

First, the actual relevance of the current surge in patenting for economic development remains less clear. While the growth rate of the patent filings by Chinese nationals is skyrocketing, the patent filings by foreign companies in China only smoothly increased over the past years. This is one indication that the technology market in China can in fact only absorb a limited number of new technologies and that the huge numbers by Chinese national applications are way beyond this absorptive capacity. Arguably, foreign companies would file more in China if made practical sense and paid. For the moment, however, foreigners from most countries file more patents in the USA than they file in China and American companies file more patents in Europe than they do in China.

Second, China remains dependent on strengths in a few, specific fields, even if some of these might be the fields of the future. At the SIPO the portfolio of Chinese inventors is rather balanced. Computer technologies, electrical machinery and basic mechanical chemistry stand out slightly in absolute numbers. The shares of almost all other fields are around or below 5% of all patent filings. With a view to transnational filings, in contrast, China's application remains limited to a few areas of high competitiveness, namely information and communication technologies. More specifically, a small number of enterprises files the majority of transnational patent applications originating in China. Huawei (about 4,000 applications in 2015) is by far the largest patent applicant from China on the transnational stage and files numbers of applications similar to multinational enterprises from other countries (*e.g.* IBM, Siemens, Philips *etc*.). Overall, the top 10 (not top 10%!) companies from China are responsible for about 35% of Chinese patent filings at the transnational level. The top 35 companies cover about 50% of all filings. These top applicants are mainly active in information and telecommunication technologies (ICT), as well as micro-electronics.

Thirdly, China does not yet display a high correlation between patents and exports that is typical for established innovation-driven economies, in which international patenting backs exports and secure technological markets abroad (Frietsch *et al*., 2014). In China, the export portfolio almost perfectly matches the country's patent specialisation only in those fields, in which it has come close to the global technological frontier: communications and broadcasting engineering, computers as well as optical and measurement technologies. In parallel, however, positive export specialisation indices exist for office machinery and lamps, batteries and a number of other, nominally "high-tech" fields. As these latter product groups are hardly backed by patenting, it appears that significant segments of China's export performance still build on either lowcost production or mere assembly with minor R&D and technology input. Even if local technological capacities are clearly increasing, Chinese trade data thus remains difficult to interpret along standard classifications of "low-tech" and "high-tech".

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[16] World Bank: World Development Indicators, Table 5.13 Science and technology; http://wdi.worldbank.org/table/5.13

Finally, World Bank[16] statistics demonstrate that there is only a marginal decrease in the share of IPR payments over receipts for the years since 2001, which is one indication of technology dependency. In addition, the OECD has shown that while for the years up to 2011 the domestic value-added content of China's exports increased significantly compared to previous periods, hardly any changes in import substitution and high shares of foreign embodiment in national exports in certain sectors remained, among them ICT with more than 63% (OECD, 2015).

6. Concluding Remarks

The Chinese research and innovation system has considerably changed overin the past 10-15 years. It was adapted to new needs and demands, emerging from the overall economic success, but also from external requirements for structural changes like digitalisation, new technologies or global economic framework conditions. The guiding idea of the induced changes and reforms is, on the one hand, to turn China from a low-cost economy to an innovation-driven economy. This is seen as the next evolutionary step for the further economic development and to overcome the so called middle-income trap. Efficiency/productivity as well as quality are seen as the vehicles to achieve this goal. On the other hand, next to the economic stability also the social and political stability with the absolute claim of power by the Communist Party is a core task that also affects research and innovation.

In governmental documents and public speeches the role of the market is repeatedly emphasised. However, that should by no means be misinterpreted as a sign that the Chinese leadership intended to introduce any sort of market-liberal economic system - even in the long run. Instead, they intend to pursue the "Chinese Dream" by setting up an at best semi-capitalist economic structure with a strong and active role of the state and more recently, a quite marked return of explicitly socialist elements and governance mechanisms that reaches far beyond the core group of major state-owned enterprise. They call this the 'Chinese Way', which is neither the one nor the other, but a 'modern socialist country' as President Xi called it at the 19th party congress in October 2017.

Over the past two decades of the Chinese enormous economic growth, the true belief of several Western spectators and policymakers was that China enters the Western development path (Fukuyama, 1992). According to the role model of other Asian countries like Japan, Singapore, or also the area of Taiwan, it was expected that China's economic development would be similar. Moving from labour to more capital-based production and also moving from imitation to innovation strategies, with all its consequences, for example like the adoption of Western intellectual property rights, standards and norms, and even societal organisations, was foreseen. Many scholars (Fukuyama, 1992; Minzner, 2018) and policymakers expected China to become a 'capitalist market economy' as well as the implementation of political reforms – some even anticipated a democratisation of China. In this perspective, the deviance from this Western role model was just a temporary phase of 'not-yet-developed' institutions.

However, there were also always scholars and spectators who took a different position. China has been considerably different from the West as well as from other industrialised countries in Asia – and China will be different at least for the coming years. "… China should not be analysed in the same way as developed, free-market, capitalist national economies because, simply put, it is not free, capitalist, or, as a matter of fact, truly national." (Breznitz and Murphree, 2010, p. 9). So on the one hand, in

Western countries it is time to wave good-bye to the ideas that China assimilates. On the other hand, also the idea of the modern economic Eldorado in Asia – the land of gold – that provides the world with low-cost products and buys high-tech goods from Western companies is also over. Sooner rather than later, the Chinese market will be the largest national, homogenous market in the world. And it will keep on growing for a while, at least from what can be seen from today's perspective – as long as the debt crisis does not surface (Preziosi *et al*., 2019). Chinese industry will improve its competitiveness in several sectors in the coming years – nationally and internationally. The core question is, if they will do it with fair or unfair means. Reported challenges are - like in previous years - intellectual property issues as well as finding and keeping qualified personnel. Without any doubt, it is important to insist on fairness and non-discrimination. At the same time one should be prepared for unfairness and discrimination – or simply stop doing business in China.

The nowadays often demanded 'level-playing field' not only means that China needs to accept and implement internationally agreed rules and institutions – which is for sure a legitimate demand. It also means that Westerners accept the differences and that the Chinese Way and the Chinese 'market economy' will not be the same like in Europe or North America. This insight and the acceptance, by the way, then also offers a basis for improved strategic acting. Waiting for the day when China assimilates was never a reasonable option.

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