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The development of China's R&I system in the past 10 years

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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 puts 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 national applicants file more patents in China than foreign applicants (Frietsch and Wang 2009).

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. This was – and still is – the foundation of the Chinese aim to shift the national economy towards an innovation-driven economy and to become more independent of technology imports. According to World Bank[2] statistics, however, 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

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

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

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).

The term "indigenous innovation" and anything that is connected to it was heavily criticised as techno-nationalism (Suttmeier 2014). 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). In the second half of the last decade the term "indigenous innovation" has hardly been used any more, but – so the argumentation in this chapter goes – the underlying policy was never given up. The rhetoric of president 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 (see Chapter 4) 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.

Next to the MLP and the 'Chinese Dream' that sets 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. It formulated three main aims that were then put forward by the 19th National Congress of the Communist Party of China in 2017 as the three strategic goals for achieving a socialist modernization of China. "It pledges that China will be an “innovative nation” by 2020, and an international leader in innovation by 2030. The third step of the strategy will be establishing China as a world powerhouse of scientific and technological innovation by 2050."[3]

This discussion paper intends to describe the current status of the Chinese science and innovation system – mainly on the national level – as well as the developments of the past about 10 years that led to this current status.

3 http://english.gov.cn/policies/latest_releases/2016/05/20/content_281475353682191.htm

2 Innovation system: overview of the Chinese economy and the government's plan

The economic performance of China has considerably increased in the past years even after the country was also affected – though not as severe as many other countries (Minzner 2018; Frietsch et al. 2017) – by the global financial crisis in the period 2007-2009. However, growth rates slightly slowed down at the beginning of this decade. The government under Xi/Li introduced the so called 'New Normal' economic growth goal of below 7% per year instead of the previous growth rates well above 7 percentage points and even two-digit growth rates in earlier years. As a consequence of the crisis the Chinese government declared the intention to become more independent of international markets and further develop the domestic consumption instead. The overall change of the economic value creation from a cheap-labour-based economy to an innovation and high-tech-oriented economy was thereby continued as it was already laid out in the Mid- to Long-term Plan for the Development of Science and Technology (MLP) in 2006 and continued by the Xi/Li government with the National Innovation-Driven Development Strategy in 2016.[4]

Already in 2012 when Xi Jinping took office for the first time he formulated his "Chinese Dream", which essentially called on the patriotism of the Chinese people – which may be viewed a populist approach, similar to political trends in many Western countries in past years.

We currently (summer 2018) see that these ideas and perspectives are continued and even further stressed after the 19th People's Congress in March 2018, when Xi Jinping's second term started. In addition, he was able to further strengthen his power and the claim to power of the Communist Party for example with the reform of the Chinese Constitution, where Xi Jinping was put on the same level with Mao and Deng and in particular, where the restriction of the presidency to two terms was abolished. In consequence, Xi could be re-appointed infinitively by future People's Congresses.

A recently often referred guideline for policy making is the so called 'Xi Jinping Thought' that stresses the claim of leadership of the Communist Party and sets the framework for 'socialism with Chinese characteristics', which means a combination of traditional socialist values and perspectives with modern economic factors.[5] The basic ideas were

4 http://english.gov.cn/policies/latest_releases/2016/05/20/content_281475353682191.htm

5 http://www.xinhuanet.com/english/download/Xi_Jinping's_report_at_19th_CPC_National_Congress.pdf

already formulated by President and Party Secretary Xi at earlier occasions, but the explicit phrasing was introduced at the 19th Party Congress in October 2017. Xi formulated the 'Xi Jinping Thought on Socialism with Chinese Characteristics for a New Era', as the official title goes, which can be interpreted as building on and deepening the nationalist tendencies. However, in his thought also the peaceful coexistence with other countries as well as China's environmental responsibility are mentioned, for example.

The claim of the power by the Party is one of the core points in Xi's thinking, but he refers also to reforms and emphasises socialist values and Party discipline. The anti-corruption campaign, for example, that he already started immediately after he took office as Party Secretary in 2012, is one of the means to implement this. The second core of Xi's thought is the layout of an economic system that combines capitalist with socialist aspects. In many speeches and governmental publications – including strategies like Internet Plus, Strategic Emerging Industries, or Made in China 2025 – a strengthening of the role of the market is mentioned. What raised hopes by many Western spectators for market liberalisations or what has been criticised by others as being propaganda and talking without action, is rooted in the obvious conviction that neither socialist nor capitalist market functions exclude each other nor are they contradictory. When Xi proclaims a stronger role of the market, then he does not refer to the (neo)liberalist perspective or Adam Smith's invisible hand, but a state controlled market, where the government plays an active role (Schüller 2018). The 'Xi Jinping Thought' takes over from 'Deng Xiaoping Thought' where he had formulated his vision on the national development and the introduction of capitalist elements. However, with Chairman Xi the socialist aspects might get stronger emphasis.

3 Public/private funding and output indicators

China's investment in building up a national innovation system were 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, when he called for more 'craftsmanship' in the production. In consequence, for the coming years the Chinese leaders announced[6] a quality initiative that will not only address industry, but

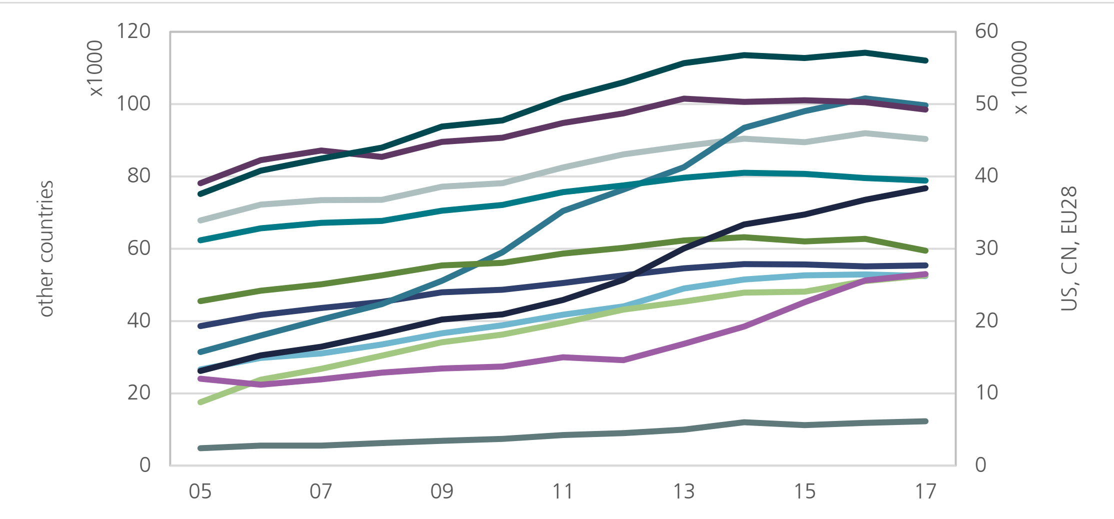
6 See 19th Party Congress in October 2017: http://www.xinhuanet.com/english/special/19cpcnc/index.htm

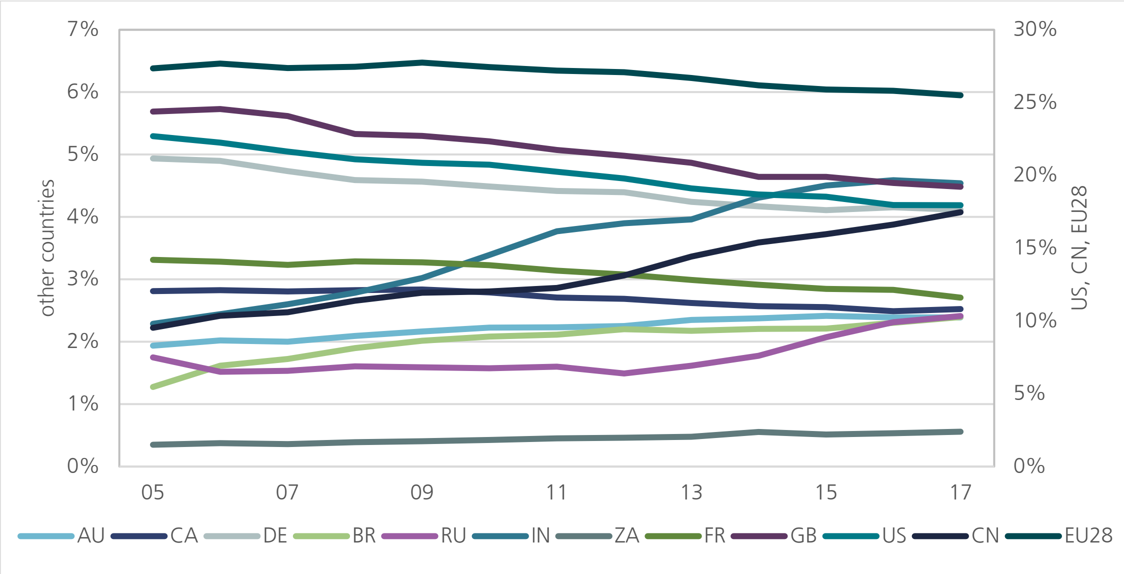
also the science system. Institutional and organisational reforms - for example of the funding system, the CAS (see Chapter 4) or also market liberalisations like removing the joint venture force e.g. in the automobile industry - will support this, but one can also expect that there will be strong monetary incentives as well as clear and high aims set by the forthcoming plans. The implementation of the quality strategy, however, still needs to be drafted in detail.

3.1 The performance of the science system

The top-notch of the Chinese science system is built around a few top research universities – the group of the so-called C9 – and a number of relevant and influential academies, namely the Academy of Sciences (CAS), the Academy of Social Sciences (CASS), and the Academy of Engineering (CAE). While the CAE is solely an advisory body, the CAS is apart from a ministerial level agency and an advisory body with elite scientists, also responsible for 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 the municipal level. 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. Policies supporting these efforts to increase the scientific output had so far mainly the aim of increasing the absolute numbers – so it was a quantity-oriented strategy. For the future, also quality-oriented support measures are to be expected, but are not yet defined.

Figure 1: Absolute numbers and shares of journal publications in the Scopus database, 2005-2017





Source: Elsevier – Scopus; Frietsch et al. 2018

One indication of the scientific capabilities are publications in scientific journals. Several of them are in Chinese only and therefore mostly invisible for international communities, but publications in international journals with peer review processes and targeting international audiences are a well-established data source. In the year 2017 Chinese authors published more than 380,000[7] journal articles in total covered by the Scopus database, an average annual growth rate (CAGR) since 2005 of 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 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.

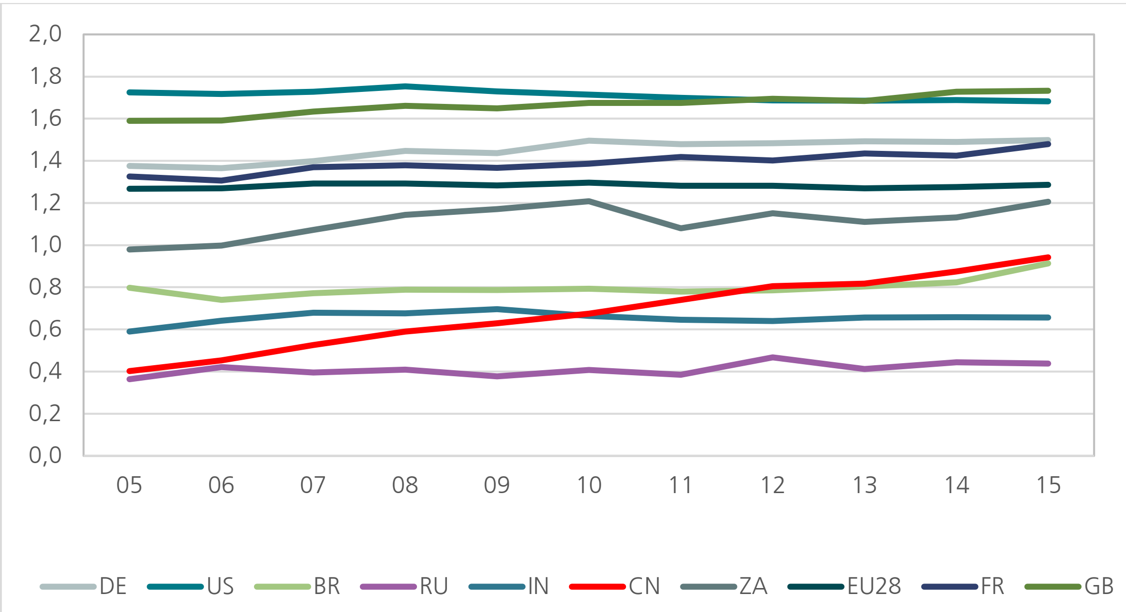
Next to this impressive increase of the total output, also the quality of these papers in terms of citations increased – on average. While in 2005 Chinese publications received 0.4 citations (field-specific) on average, the indicator values doubled until 2012 to 0.8 – this means on average a Chinese publication receives 20% less citations than the world average – and further increased to a value close to the world average of 1.0 in

7 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 author co-publish a paper, 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.

the year 2015.[8] In individual disciplines China had already reached level even beyond the world average, for example in plant molecular life sciences (Jonkers 2010) in materials research (Frietsch and Tang 2008) or in genetics (Frietsch and Meng 2010), just to name a few.

Within the group of BRICS countries, China is the only one with a strictly positive trend over time. South Africa, on the other hand, yields the largest average number of citations in this group. Brazil and China are on a similar level and Russia brings up the rear among the BRICS countries. The EU-28 reached a rather stable value of 1.3 throughout this period, meaning that EU-publications received about 30% more citations than the worldwide average. Also concerning the Excellence Rate – this is the share of a country's publications that belong 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.

Figure 2: Average citation rate (field specific) for BRICS and selected industrialised countries



Source: Elsevier – Scopus; Frietsch et al. 2018

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

The science system, one could conclude at this point, is in good shape and performs rather well. While there is still a focus on quantity instead of quality, but 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 China already today conducts excellent research, for example in materials research, nanotechnology, super-computing or genetics (Frietsch et al. 2008).

3.2 Patent output – light and shadow

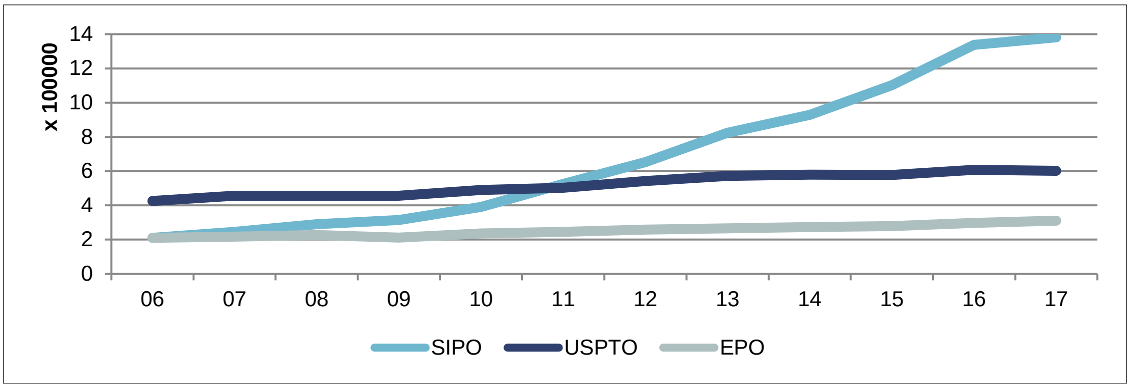
Another important column of the innovation system is – of course – industry. In this case the assessment of the Chinese performance is less clear. At the national market in China, competitiveness seems to exist in many sectors – in some of them with the help of government regulations with tools like mandatory joint ventures or investment restrictions –, whereas abroad the technological and product portfolios as well as the technological competitiveness are limited and focus almost exclusively on information and communication technologies (ICT). Therefore, a differentiation between the national and international performance of Chinese industry seems appropriate. The Chinese national economy and with it a number of Chinese companies – be it privately owned or state owned enterprises – flourish by the huge increase of national demand. In addition, foreign companies were and still are doing good business in China and benefit from one of the largest and fastest growing markets in the world (European Chamber 2018: 11).

The Chinese technological strength in the national market manifests itself in huge numbers of patent applications. The National Intellectual Property Administration (formerly known as State Intellectual Property Office, SIPO) now under the State Administration for Market Regulation counted almost 1.4 million applications of invention patents in 2017.[9] In comparison to this the United States Patent and Trademark Office (USPTO) receives about 600,000 of such patents per year and at the European Patent Office (EPO) the annual inflow is about 300,000. Therefore, the question arises, what is technologically behind these 1.4 million patent applications and especially what are the social costs of this huge amount of documents compared to a most probably very lim-

9 http://english.sipo.gov.cn/statistics/2017s/201712/1111449.htm

ited quality.[10] The high numbers as such are the consequence of a quantity-oriented policy combined with the quest for economic success. The conviction that technology and innovation are the mean for economic success and that IPRs are the certificates or tokens of that game, was preached by political leaders, and has been accepted as such and acted upon by many. 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 only absorb a limited number of new technologies and that the huge numbers by Chinese national applications are way beyond this absorptive capacity. The underlying assumption behind this is that foreign companies would file more also in China if it would pay and make sense for them, similar to other relevant markets. For example, foreigners from most countries file more patents in the USA than in China and US-American companies file more patents in Europe than they file in China.

Figure 3: Number of patent applications at three patent offices



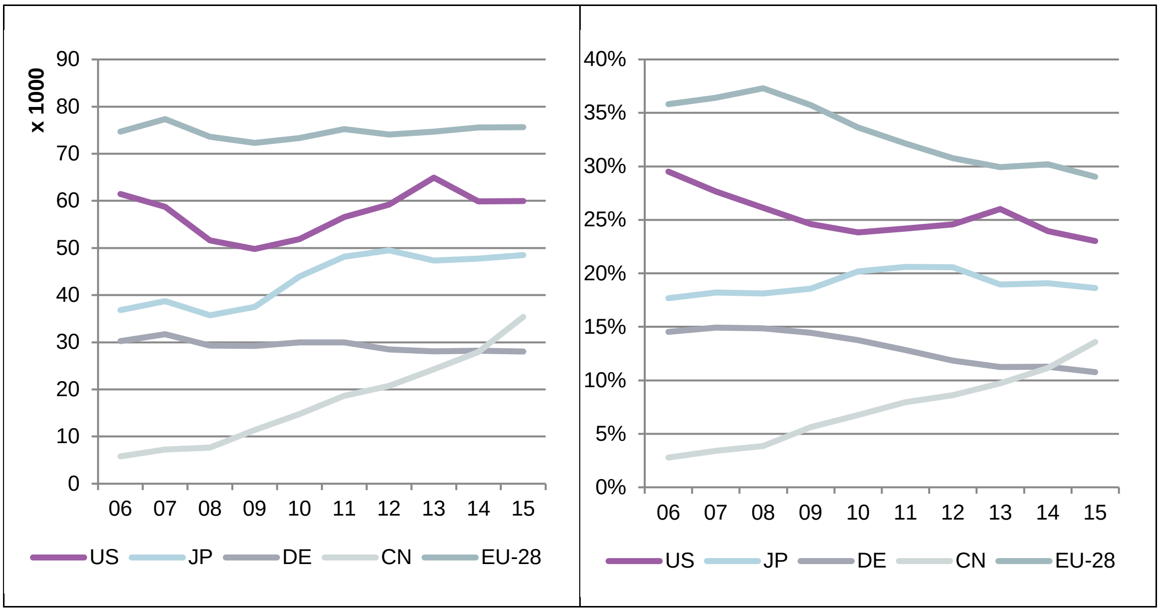
Source: Annual reports and statistics by SIPO, USPTO and EPO; own compilation

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.

10 The quality of Chinese patents at SIPO can hardly be assessed. The grant rate – this is the share of patent applications that the SIPO finally grants a patent – is much higher than at the EPO and even higher than at the USPTO. This, however, is most probably not a consequence of the high quality and uniqueness of the patent applications, but rather of the low threshold that the SIPO examiners apply. Furthermore, patent citations – a frequently used measure of quality and relevance, similar to citations of scientific publications – are not available for analyses. The citations of the Chinese filings abroad, however, receive on average lower citation numbers, which can at least be seen as a hint for the lower quality in China as well.

The Chinese performance abroad, different to the national level, is also growing very fast, but it is still limited to a few areas of high competitiveness, namely communication and especially information technologies. This extreme dependence on a few technological competences and the core of Chinese competitiveness – namely cheap labour – is documented both, in patent applications outside China as well as the export portfolio (see below).

Figure 4: Transnational patent applications by selected countries



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

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. Brazil (3.8%), India (8.5%), and Russia (2.1%) have also been able to increase their patent output, while South Africa's patent numbers at the transnational level have been shrinking at an average rate of 3.5% since 2006.

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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.

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]

Only a small number of enterprises, with a large tail of very small applicants, files the majority of 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 like the largest enterprises from other countries (e.g. IBM, Siemens, Philips etc.). The top 10 (not top 10%!) companies from China are responsible for about 35% of the Chinese patent output 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.

In consequence of the R&D activities and the patent application behaviour at the transnational level, China shows comparative advantages [14] by patents in communications as well as broadcasting engineering, computers, optical and measurement technologies. Slightly positive values exist also for electronics and – interestingly – recently for rail vehicles.

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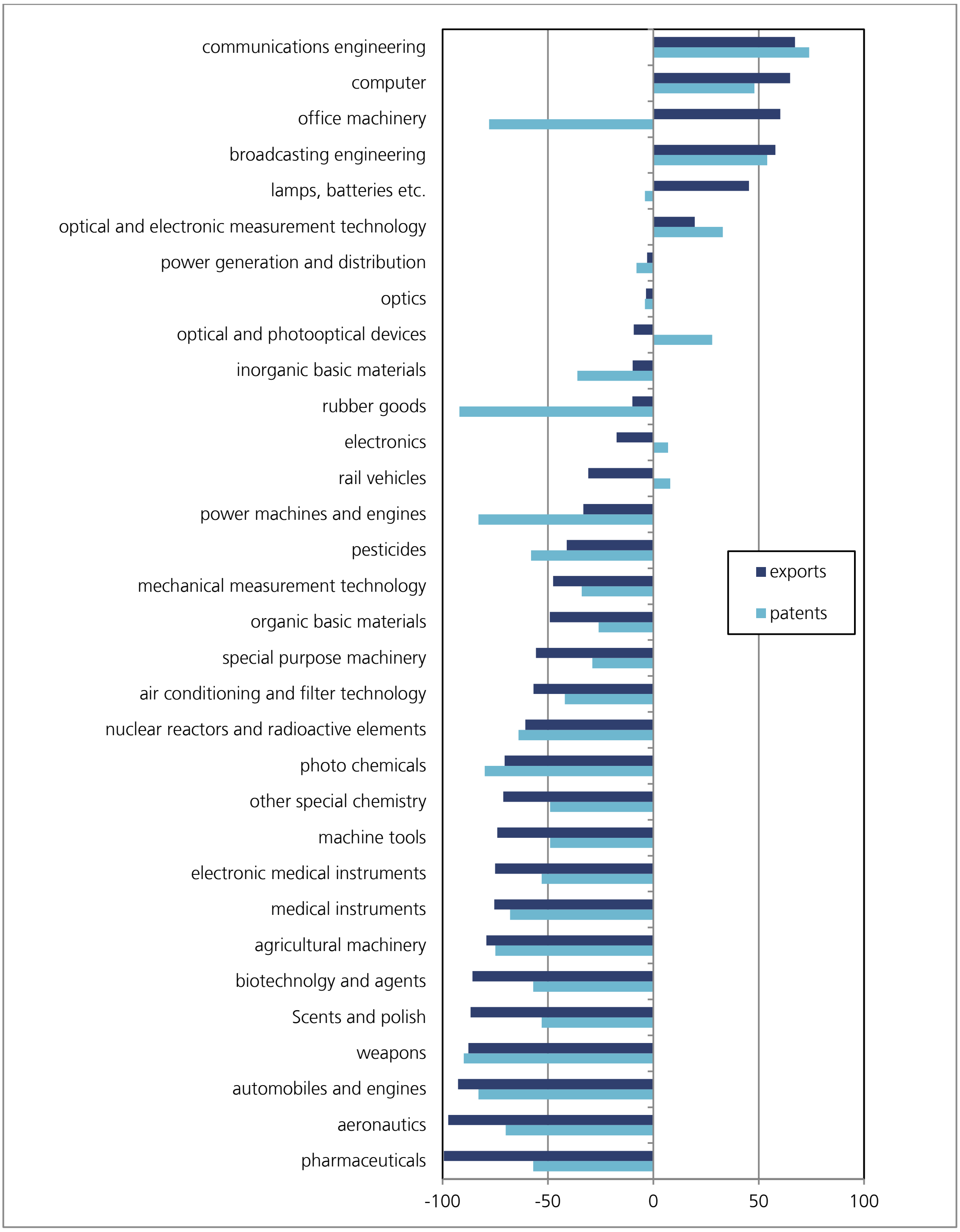
12 Transnational patent applications are defined as patent families with at least a PCT or an EPO family member (Frietsch, Schmoch 2010).

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 The comparative advantage is measured by the so called specialisation index (Revealed Technology Advantage, RTA), which sets the share of a technology in a country in relation to the share of that technology worldwide (shares in terms of patents). For further methodical explanations see https://consultation.onlines3.eu/2-6-specialisation-indexes-ff47c25542d8. Here a transformation of the index is used for better interpretability. The logarithm centers the function around the average value of zero and the hyperbolic tangent fixes the distribution between -1 and +1. For better interpretation the results are taken times 100 so that the index varies between -100 and +100 with zero as the average.

Figure 5: Patent and export specialisation index for China (Patents: 2013-2015; exports: 2014-2016)



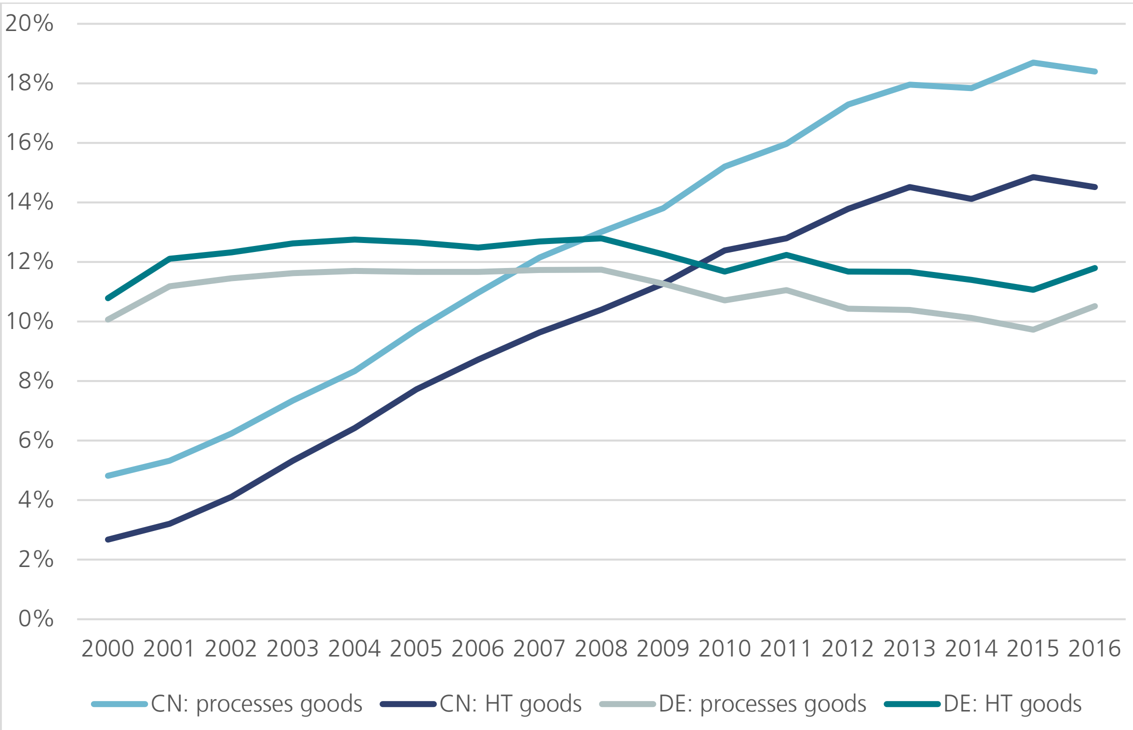
The index is calculated as the share of a countries exports/patents in a particular field in relation to the worldwide share of that field. After transformation, zero indicates world average while positive/negative index values indicate shares above/below the worldwide average.

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

3.3 Trade data as indications of economic competitiveness

International trade is a signal of the attractiveness of goods and services provided by a country as well as the national demand for such goods reflected in the imports. At international markets companies meet their competitors at rather equal conditions. In consequence, the export performance reflects the competitiveness in certain technologies/sectors. The import-export relations offer insights into the competitiveness at the national market and the potential for import substitution is reflected in the trends over time.

Figure 6: Shares of worldwide trade for China and Germany



Processed goods are SITC categories 5-8; HT goods are high-tech goods defined as goods with average R&D intensities of more than 2.5% (see Gehrke et al. 2013).[15]
Source: UN - COMTRADE; own compilation

International patents support exports and thereby secure technology markets so that a high correlation between patents and exports exists (Frietsch et al. 2014). This also holds for China, where the export portfolio almost perfectly resembles the country's patent portfolio on a global scale. Comparative advantages concerning exports occur, similar to the patent portfolio, in communications and broadcasting engineering, in the

15 https://www.e-fi.de/fileadmin/Innovationsstudien_2013/StuDIS_08-2013-NIW_ISI_ZEW_engl.pdf

exports of computers as well as optical and measurement technologies. In addition, positive specialisation indices exist for the exports of office machinery and lamps, batteries etc. These latter product groups are hardly backed by patent specialisation indices, suggesting that China's competitive edge either builds on imports or on the production of low-tech products with minor R&D and technology input.

The analysis of general trends in foreign trade data reveals further insights (see Figure 6). For many years, Germany was the largest exporting country of processed goods in the world (in absolute terms), but since about the year 2008 – in the case of high-tech goods since 2010 – China is the largest exporting country. The share of Chinese exports in worldwide trade was well above the mark of 18% in the years 2015 and 2016. For all processed goods, the share is about 15%. Germany, in comparison, still reaches a share of about 12% in high-tech goods and about 10% in processed goods. China reached a trade surplus (exports minus imports) in low-tech goods already before 2001, but it achieved a trade surplus in high-tech goods only after 2007.

As an export-oriented country, with high shares of global exports and a considerable integration into international value chains, also China was hit by the Financial Crisis in 2007-2009. Most of the economic trends and indicators still kept a positive development, but were slowed down. For example, the number of transnational patent applications kept on growing. Chinese exports, however, decreased by 16% in 2009 compared to 2008 after growth rates of more than 30% in previous years.[16] In consequence, the Chinese State Council released an economic stimulus package – like many other countries did as well – to support the national economy mainly by infrastructure investments. Furthermore, they formulated the intention to become less dependent on international markets and to develop the national demand instead.

Indeed, according to World Bank data, China has been able to reduce the share of exports of goods and services as a share of GDP from about 35% in 2007 to about 20% in 2017. The EU-28 countries have increased their shares from 38% to 45%. The USA reached a level of about 12%, which is rather stable over time with slight increases after the Financial Crisis.

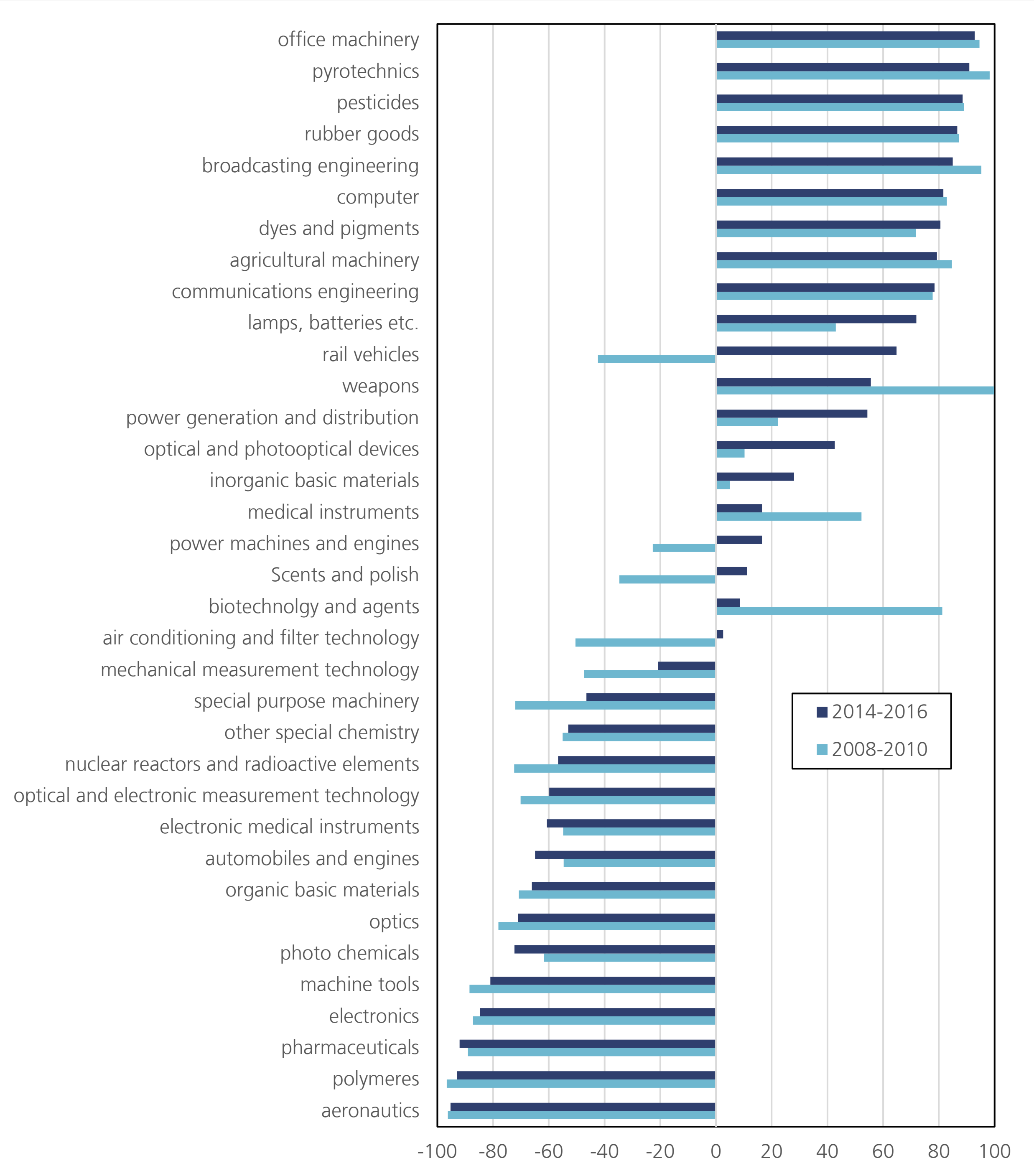
The Revealed Comparative Advantage (RCA), an indicator to measure how national industry prevails over foreign competitors at the national market, takes into account the export-import-relation and can be interpreted as national competitiveness at national markets. It also indicates trends of import substitution. Between 2008-2010, when the economic stimulus package was released, and the period 2014-2016, the RCA took a

16 Own calculations based on UN – COMTRADE; exports are in current prices.

positive development for Chinese industry in many sectors, for example in parts of chemical products like inorganic basic materials or scents and polish, in mechanical engineering fields like power machines, special purpose machinery and especially rail vehicles (see Figure 7). This indicator shows a decrease in only few fields like biotechnology and medical instruments. This means that Chinese firms – including foreign-owned companies producing in China – became more competitive at the national markets in most areas. This interpretation needs to be put into perspective of regulations and framework conditions set by the Chinese government, which – of course – massively intervenes in some sectors. In some of these sectors the competitiveness is only achieved because of these kinds of interventions. One example is the national demand for wind energy installations, where the public procurement only allows national firms so that international competitors were crowded out, essentially.

In sum, even though China is the largest exporting country of processed goods (SITC 5-9 categories) as well as high-tech goods in the world and the shares in world trade have been increasing, China managed to develop its national market and became more independent of international markets and exports. The shares of exports over GDP decreased to a current level of about 20% – a level less than half of that of the EU-28. The Chinese value added in trade also increased in the past years and the competitiveness of domestic enterprises – including Chinese as well as foreign-owned enterprises – at the national market also increased considerably in many sectors over the past ten years.

Figure 7: Revealed Comparative Advantage (Export-Import-Relation) for China, 2008-2010 versus 2014-2016

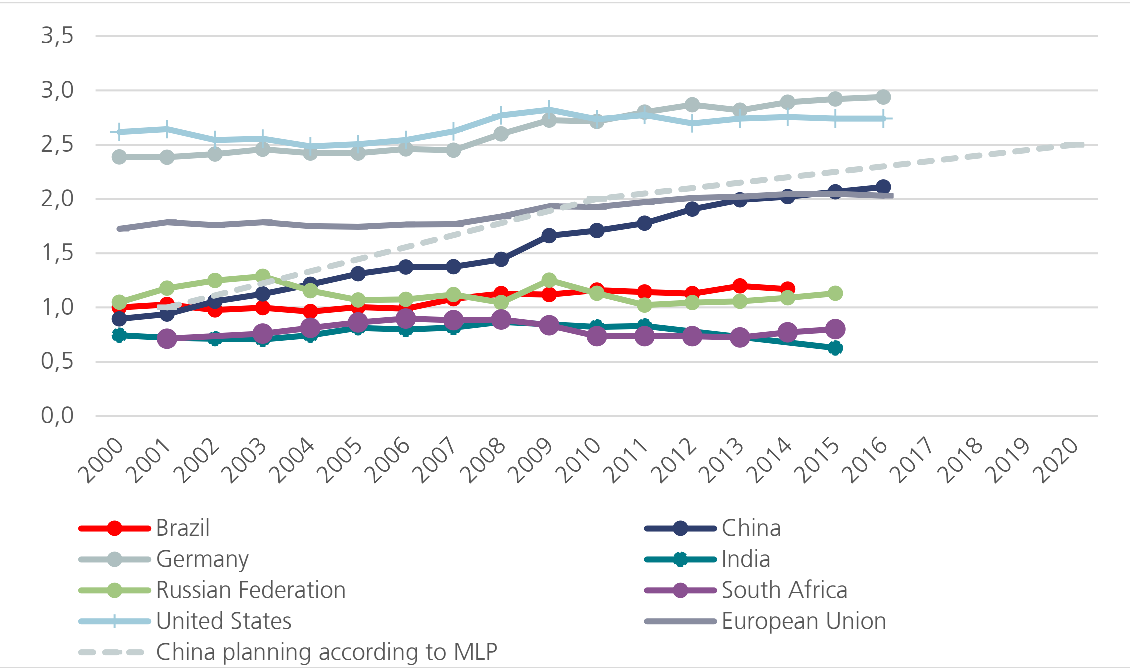


Source: UN - COMTRADE; own compilation

3.4 Research and development – investments that lay the foundation for scientific and economic successes

Further statistics and indicators support an assessment of a strong Chinese national industrial innovation system. For example, the R&D intensity – this is the share of total R&D expenditures (GERD) over GDP – of meanwhile more than 2% documents a strong will and the success of the innovation policies of the Chinese government. China has surpassed the EU-28 recently in terms of R&D intensity and aims at further increasing its R&D intensity to 2.5% by 2020. According to the available data the country is close to the planned figures from the MLP or the goals put forward, for example, in the 12th FYP (2011-2015) of 2.2% at the end of that planning period (Huang et al. 2016). However, China has left other countries far behind like Brazil (1.2%), Russia (1.1%) or India (0.6%), which is the only country with decreasing shares, as well as South Africa (0.8%).[17]

Figure 8: R&D-intensity (total R&D expenditures as a share of GDP) for China and selected regions/countries, 2001-2016



* Data for China in 2016, Germany 2015 and 2016, South Africa 2014 and 2015, United States 2015 and 2016 stems from OECD (2018); data for the European Union 2016 stems from Eurostat - rd_e_gerdtot.

Source: Worldbank – WDI; Eurostat – rd_e_gerdtot; OECD – MSTI

17 OECD - MSTI database.

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 the USA or Germany as well as the EU-28 average are much lower than that. These statistics reflect the side of the sector of performance. In China – similar to other countries with state owned enterprises –, business R&D (BERD) includes, private, semi-private as well as state owned enterprises. Astonishingly, when the business expenditures on R&D (BERD) are analysed in terms of the sector of funds, the shares of the business sector is also much higher than in most other countries. According to the S&T Statistical Yearbook (NBS, MOST 2017) almost 95% of the expenditures by the business sector are funded by self-raised funds and only about 4% are funded by government and less than 1% are foreign funded. In the European Union 82% of BERD are funded by the business sector and even in the USA it is only 88%. The lowest value in this respect is reached by Russia with 34% of business funding and 63% of government funding of business R&D, respectively. So are the Chinese data wrong or even fake? The answers are yes and no. No, because the statistics follow the definition also used by OECD or Eurostat. Indeed, the Chinese government mainly directly funds universities and public research organisations, but less so R&D in companies via funding programmes. In addition, there is empirical evidence that the selection and distribution of these direct funds for companies are mostly distributed based on the application and the performance of the company, but in the last years, increasing shares seem to be distributed based on *Guanxi* (Wang et al. 2017; Chen et al. 2018). *Guanxi* can best be translated as 'individual network', similar to the meaning in Western countries, but plays a more important role in Chinese culture.

Yes, the statistics are wrong or at least misleading for maybe two reasons. First, China offers considerable tax reductions to so-called high-tech firms, defined by their R&D intensity (share of R&D expenditures over turnover). Firms tend to claim this status by reporting more R&D expenditures than they really have. Therefore, not only R&D statistics by sources of funds, but also the total R&D expenditures (GERD) might be overestimated. This, however, cannot be quantified and is only derived from interviews and informal talks. At the same time, however, there are analysts who claim that the Chinese R&D expenditures are underestimated (see for example Sun and Cao 2016; Sund and Cao 2014). Second, companies all around the world usually do not fund their R&D activities by loans, but mostly by cash flow (Schubert, Rammer 2016). The reason for this is that R&D is a risky and uncertain endeavour so that debts on unsuccessful processes would put burden on the overall business and might even lead to bankruptcy. Chinese companies, mainly state owned enterprises, receive considerable funds from the government via public loans, which in some cases are not paid back or are most probably provided on very favourable conditions. While these loans are not used for R&D directly, they might free other sources, which can then be invested in R&D, indirectly increasing the R&D expenditures, while the source of these funds is not government, from a statistical point of view.

4 Summary: A critical analysis of framework conditions for R&I

The Chinese innovation system considerably caught up with industrialised countries and reaches top ranks in absolute terms in many dimensions (Huang et al. 2016), including those measured by structural or quality-oriented indicators. Among them are R&D intensity, citation rate of scientific publications, or patent applications shaping international markets, in which China reaches values similar to the EU-28 or OECD averages. The policies and reforms of the past years were well selected and elaborated to support the economic development from a developing to a (mostly) developed country (Gu et al. 2016). In addition, the recent ambitions and policy plans raise expectations for further economic successes also in the future.

However, also in the future China will not be able to walk alone. For many years the inbound foreign direct investment (FDI) into China was increasing, but since about the year 2014 the inflow is decreasing. At the same time the outward investment decreased for the first time in 2017, due to new regulations (Hanemann and Huotari 2018).

The share of international co-publications was increasing over the past decade and meanwhile reaches a level of about 20%. Given the size of the country – or to be more precise, the absolute numbers of publication outputs – similar shares like in the USA of about 30% can be expected. The future will show where China goes also in this direction, but the recent policies and framework conditions might hamper international collaboration. Regulations and state controls are expected to have a restrictive effect. For example, the 'Notice of the Organization Department of the Central Committee of the Communist Party of China on Further Strengthening the Administration and Supervision of Leading Cadres' Overseas Management' sets the rules also for international collaborations, visits and exchange. Given the punishments and the potential threats that individuals might learn also from processes for example in the context of the anti-corruption campaign, researchers are more cautious in following the rules. They more often than not act 'better safe than sorry' with the effect that some exchanges do not occur at all. Therefore, these regulations might reduce the abuse of public funds, but also the openness and opportunities for exchange.

On the other hand, Western countries might change their collaboration behaviour and reduce their efforts, due to disagreement with the policies or astonishment about the new nationalist tendencies and language. They might not directly pull out or stop their running programmes, but they might not set up new programmes or start fewer programmes.

It is therefore very important for future collaborations that the governments support joint programmes and opportunities for exchange. The new framework programme Horizon Europe will explicitly address collaborations with third countries. In addition, at the national level in Europe there are many examples of joint activities. Also on the Chinese side, so far there is no reason to believe that the open science and exchange policy will change. In the 'Xi Jinping Thought', for example, but also in 'Made in China 2025' (see next chapter) international exchange and collaboration as well as co-existence are made explicit, but it remains to be seen to what extent it will be followed-up by concrete actions.

The share of European companies doing business in China that are pessimistic about their business outlook has increased in 2016 and 2017 compared to previous years (European Chamber 2018: 28). This might just be a snapshot of the current expectations and attitudes, but reforms need to be pursued and implemented so that the intended effects by Chinese policy makers will appear. China – being mostly a developed country nowadays – faces different challenges than 15 years ago. Productivity growth, in particular in state-owned enterprises but also in public research organisations, is one of the biggest challenges on the way to an innovation-driven economy. Institutions and framework conditions need to be reformed to tackle this challenge. Several of these reforms are already underway, for example, in public R&D funding or the layout of the science system. Further reforms are already announced, thought yet unclear in their detailed implementation, for example on strengthening basic research or increasing the quality in industry and public research alike.

One way of doing this is 'strengthening market forces', which is a constant rhetoric of policy makers in China. One of these aspects considers the investment liberalisation in certain sectors, for example, the financial sector, which was announced earlier this year.[18] Therefore, there are several examples of market opening. However, what for-

18 https://www.reuters.com/article/us-china-boao-pboc/china-pledges-to-allow-more-foreign-investment-in-financial-sector-by-year-end-idUSKBN1HI074

eign spectators need to understand and/or accept is the difference between the Chinese perception of market forces and the Western perception of it. Chinese policy makers define the state/government as a relevant and active actor in the market(s) and not just a provider of framework conditions. This is the core idea of the 'socialist system with Chinese characteristics'.

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