STI China

SCIENCE TECHNOLOGY AND INNOVATION PERFORMANCE OF CHINA

D9: Final Report

July 2014

Sociedade Portuguesa de Inovação

UNITED NATIONS UNIVERSITY
UNU-MERIT

AUSTRIAN INSTITUTE OF TECHNOLOGY
TOMORROW TODAY

Science, Technology and Innovation (STI) Performance of China

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Executive Summary

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Executive Summary

This report is Deliverable 9: Final Report of the Science, Technology and Innovation (STI) Performance of China study (N° RTD-2011-C6-China).

The study's objective is to assess the evolution of China's STI Performance and analyse its economic impact on Chinese productivity and competitiveness and on the global markets, taking into account the differences between various Science and Technology fields, economic sectors and types of actors involved.

The major role assumed by China in STI fields brings **new challenges and opportunities** for Europe:

- Challenges, because China has entered higher value added segments of global production and linked with economies of scale can compete with European production;
- Opportunities, because the new technology generated by the increasing and sustained R&D investments can provide a wealth of opportunities to expand the boundaries of global knowledge, feeding and accelerating the process of innovation.

In that context, the study had the following **goals**:

- Identifying, assessing and updating the data and indicators relevant to STI in China;
- Mapping China's research and innovation capabilities in selected technologies as well as their translation in the development of its industry;
- Providing a description and an assessment of China's efforts and policies to develop its STI capabilities, including its international strategy;
- Characterizing the framework conditions for innovation, providing in particular an overview of China's innovation system;
- Pinpointing opportunities and challenges brought about by the STI development of China.

The study was implemented by the consortium of Sociedade Portuguesa de Inovação (SPI), The United Nations University - Maastricht Economic and Social Research and Training Centre on Innovation and Technology (UNU-MERIT), and the Austrian Institute of Technology (AIT). It ran from December 2012 to August 2014. In order to achieve the goals, the key methods utilized in the study include bibliometric research, desk research, interviews, survey questionnaires, workshops, and analysis of existing data and literature.

The study aims to help inform and develop STI strategies for the European Union (EU) considering the emerging role of China as a competitor and partner of the EU.

This report provides the results of the activities conducted in the project Work packages (WP)s. These results have been summarised separately for *WP1: Identifying, assessing and updating data and indicators relevant to Science, Technology and Innovation in China* and *WP2: Mapping of China's research and innovation capabilities in selected technologies*. Following this, the results of *WP3: Assessing China's policies in terms of development of its domestic STI capabilities and its international strategy* and *WP4: An overview of framework conditions and the development and growth of innovative firms* have been summarised together since their methodologies overlapped. Finally, a summary of the analysis developed under *WP5: Draw conclusions for the EU as regard the challenges and opportunities provided by the development of China the short and medium term (5 years)* is provided.

WP1: Identifying, assessing and updating data and indicators relevant to Science, Technology and Innovation in China

The objective of WP1 was to identify those indicators which are most relevant to measuring the overall progress of STI development in China and which are coherent with the Innovation Union Scoreboard and the Innovation Union Competitiveness Report.

For the indicators which measure the extent to which innovation is 'enabled', most values for China were found to be below the EU[1] value, and also below the national value for example selected EU countries (Germany – innovation leader; the UK – innovation follower; Italy and Spain – moderate innovators; and Poland, Romania and Turkey – modest innovators). For instance, the share of

1 EU refers to the EU15 up to 2003, the EU25 from 2004, and the EU27 from 2007. EU28 data was not available at the time of writing.

population aged 30-34 having completed tertiary education was 15.2% for China in 2011. For the EU the latest value (2012) was much higher at 35.8%, but compared with Turkey (18%) and Italy (21%) the difference was smaller. In absolute terms, with 74 million people the number of Human Resources in Science & Technology (HRST) in China in 2011 was quite close to the 98 million in the EU[2]. However, the number of new S&T graduates with Science & Engineering (S&E) orientation in 2011 was 875,000 in the EU which was far below the 1.4 million in China. For China this number has increased by more than 100,000 to 1.5 million in 2012. Therefore, the especially strong S&E orientation of China's human resources remains. For a long time human capital, as an innovation input, has been seen as the main driver of S&T development. However, it can be concluded that compared to such indicators which are labelled 'enablers' in the Innovation Union Scoreboard, the increasing Chinese performance in terms of indicators for firm innovation activities, was even more impressive.

Business R&D expenditure as a share of GDP for China was 1.4% in 2012, above the EU share of 1.3%, and much above that of for instance Spain (0.68%) and Italy (0.69%), but below that of Germany (1.95%). The trend in public sector R&D expenditure (as a share of GDP) in China has not changed that much over the last 5 years. Besides the high R&D intensity of the business sector, the non-R&D innovation expenditures of Chinese firms were even more clearly higher - 1.19% in 2010 compared to 0.56% in the EU, and above the level of any of the selected countries, such as Germany and the catching-up country Poland. Although there is a difference in the definition used for SMEs, the share of SMEs innovating in-house was 17.5% for China in 2010, higher than the 11.3% for Poland and 10.8% for Romania, but lower than the EU average of 31.8%.

The innovation output indicator concerning SMEs introducing product or process innovations indicates that Chinese SMEs seemed to perform better than for instance those of the UK or Spain. Chinese SMEs (the so-called small above scale enterprises) appear to be an important new driver for the increased R&D expenditures. In 2011 their R&D expenditures were equal to 11,913 million Euro. According to the latest update for 2012 this has increased to 14,905 million. Concerning the contribution of medium- and high-tech product exports to the trade balance there has been a steady

2 Number of individuals having either successfully completed an education at the third level in an S & T field of study or is employed in an occupation where such an education is normally required. HRST are measured mainly using the concepts and definitions laid down in the Canberra Manual, OECD, Paris, 1995.

increase from 2006 to 2011. However, the economic output in terms of licence and patent revenues from abroad has remained very limited.

Using Elsevier's Scopus database, an analysis of the evolution of China's research capacity in key scientific disciplines for the years 2000, 2005, 2010 and 2011 was conducted. The analysis of the scientific fields consisted of two layers. Firstly, the general developing trends of 12 fields are presented, with the analysis focusing on the number and growth rate of publications in the selected years. The criterion in selecting key scientific fields was a combination of three areas: strong, fast growing and matching of grand challenges. Secondly, a deeper analysis is provided on collaborative research between China and the EU [3] in six selected fields - Chemistry; Computer science; Environmental science; Medicine; Pharmacology, toxicology and pharmaceutics; Physics and astronomy.

The analysis of general trends in the 12 fields indicates that the strength of research output in China appears to have a specialisation pattern which was found to be different from that of global research output. In China, the strongest fields were identified as Engineering, Physics and Astronomy, Material science, and Chemistry.

The pattern of the fastest growing fields in China was also found to be dissimilar to the global trend. The emerging fields of Immunology and microbiology have been booming in China. Existing strong fields such as engineering have shown high growth rates.

This data shows that China has a competitive advantage in natural sciences, such as Engineering, Computer science, and Materials science. On the contrary, research in social sciences, for instance Psychology and Arts and Humanities, has not progressed to the same extent.

The level of collaboration with the EU in terms of the total number of collaborative research papers was found to be similar to that with the U.S. in the studied fields. However, the share of China-EU collaborations that are published in high impact journals was lower than that with the U.S. Nevertheless, the ratio of China-EU collaborations to China-U.S. collaborations in high impact journals increased in almost all the studied fields from 2005 to 2011, indicating that high-quality collaborations with the EU are increasing at a faster rate.

3 EU refers to the EU15 up to 2003, the EU25 from 2004, and the EU27 from 2007. EU28 data was not available at the time of writing.

WP2: Mapping of China's research and innovation capabilities in selected technologies

WP2 provides a comprehensive overview of China's research and innovation capabilities across industrial sectors and in selected cross-cutting technologies. The empirical analysis provides novel insights into the development of China's research and innovation capabilities, both concerning their general development as well as their strengths and weaknesses across selected economic sectors and technologies.

The empirical analysis focused on two indicators: the development of industry R&D expenditures, widely recognized as one of the main drivers of generating new products and/ or new processes that induce added value and foster productivity growth; and patent applications. Despite several limitations, patents are the most direct indicator for the creation of new technological knowledge that is likely to be commercialized.

The sectors under consideration were defined at the NACE-two-digit level, including nine manufacturing sectors. In addition to the sectoral approach, three major cross-cutting technologies, Biotechnology, Environmental Technologies and Nanotechnology, have been analysed. These technologies do not follow the traditional industry classification, but are nevertheless of special importance, in particular in light of the EU policy towards grand challenges.

The results of the empirical analysis clearly underpin the improving performance and capabilities of research and innovation in China over the past 20 years. Though the analysis revealed significant sectoral and technological differences in China´s STI development, the overall growth with respect to patent applications and private R&D investment was striking. Most notably, the overall growth of the indicators under consideration has not been hampered by the global economic crisis.

The rise of China's scientific and technological capabilities can also be observed in the global distribution of industrial R&D expenditures which have changed considerably during the time period 2000-2009. China has increased its total R&D expenditures significantly, both in absolute terms as well as in terms of its global share in total R&D expenditures. China's global share more than doubled between 2002 and 2009, from 5.0% to 12.1%. During the financial crisis of 2008/09, a period characterized by decreasing R&D expenditures in some countries, China's total R&D expenditures continued to grow. These results convincingly illustrate the increasing importance of R&D expenditures as a driving force for generating innovation in China. They point, on the one hand, to a

deep shift in the structure of the Chinese economy with a rising share of knowledge intensive industries, in particular in telecommunications and electronics. On the other hand, they reflect considerable efforts by the Chinese government to accelerate the transformation of the Chinese economy to a more productivity-driven, knowledge based economy.

Taking a sectoral perspective, the overall impression does hold, although some differences across the sectors and technologies under consideration were observed. Results of the sectoral analysis indicate that between 2000 and 2010 the growth of Chinese industrial R&D investment was mainly driven by the 'Electrical Equipment' and 'Other Transport Equipment' sectors, followed by 'Machinery and Equipment' and 'Chemical Products'. R&D expenditures of Chinese firms in 'Electrical Equipment' and 'Other Transport Equipment' reached 70% of the corresponding expenditures of EU27 firms in 2010. However, while the growth in R&D investment in the sector 'Other Transport Equipment' in the EU[4] was, like the US, driven by high growth rates in 'Aeronautics', the driving force behind the growth of Chinese R&D expenditures in 'Other Transport Equipment' was huge R&D investment in 'Ships and Boats'.

The gap between China and the EU in R&D expenditures was found to be considerably larger in other sectors. For 'Machinery and Equipment' and 'Chemical Products', R&D expenditures of Chinese firms were around 40% of that of European firms, and for 'Motor Vehicles' and 'Fabricated Metal Products' this was around 25%. The gap was largest in 'Pharmaceuticals' where R&D expenditures of Chinese firms accounted for around 12% of the R&D expenditures of European firms.

With regard to trends in China's patent output, overall results match quite well those observed for industrial R&D investment. Chinese patenting activity before the year 2000 was very low. However, after the turn of the millennium the number of patents has been increasing steadily, reaching around 17,000 patents in 2011 (which was almost 40% of the patenting activity for the US). Taking into consideration the share in global patenting, the share of the EU and the US has been gradually decreasing – nearly in parallel – from around 43% in the year 1990 to about 25% in the year 2011. In contrast, China´s share in global patenting started to increase markedly after the year 2000. This increase has been rather significant, starting from nearly zero and almost reaching a 10% share in global patenting in 2011, with an average annual growth of 1%.

4 EU refers to the EU15 up to 2003, the EU25 from 2004, and the EU27 from 2007. EU28 data was not available at the time of writing.

The sectoral results for patents did not differ much from sectoral results in private R&D investment. China´s patent growth between 1990 and 2011 seems to stem mainly from increased patenting in the field of 'Computers, Electronics and Optical Products' as well as 'Electrical Equipment', leading to a world share in global PCT patenting of about 12% in 2011. The high patenting activity in these sectors can be mainly explained by the high number of patents related to 'Information and Communication Technologies'. China hosts two of the largest global players in telecommunications, the multinational enterprises ZTE and Huawei, which accounted for more than 30% of patents in these sectors and which also belong to the top patenting actors worldwide. Average patenting intensity, with about a 5% to 7% share in PCT global patenting, was found for the remaining sectors including 'Chemical Products', 'Pharmaceuticals', 'Fabricated Metal Products', 'Machinery and Equipment', 'Motor Vehicles' and 'Other Transport'. A lower global share was identified for the three cross-cutting technologies, showing a share in global patenting of about 5% and lower. In 'Biotechnology' and 'Environmental Technologies', the share was about 5%, while 'Nanotechnology' showed the lowest value with about a 3% world share.

To conclude, China has considerably increased its research and innovation capability as reflected by the significant increase of its share in global patenting and global R&D investment over the past decade. China's growth, however, was uneven and characterized by considerable differences across selected manufacturing sectors and cross-cutting technologies. Differences between China and the EU in terms of industrial R&D were largest in 'Pharmaceuticals' and smallest in 'Electrical Equipment'.

WP3: Assessing China's policies in terms of development of its domestic STI capabilities and its international strategy & WP4: An overview of framework conditions and the development and growth of innovative firms

The objective of WP3 was to analyse and identify the main trends in policy-making and in the funding system for STI development in China, and to study China's international strategy concerning STI, particularly with regard to the EU. The objective of WP4 was to provide an overview of the Chinese innovation system and of the consequences for innovative operators in China.

The data collection in WP3 and WP4 was provided through various methods including:

- Survey: Online questionnaires, in English and Chinese, were provided to Europe-based and China-based stakeholders. There were four specific questionnaires - for Chinese Research/ Industry Stakeholders and European Research/ Industry Stakeholders. A total of 212 responses were received.
- Fact Finding Mission to China: Implemented from 20th October to 12th November 2013 in Guangzhou, Shenzhen, Shanghai and Beijing. The mission included 30 meetings with stakeholders, including European and National Chambers of Commerce, Embassies and Consulates of EU Member States, Private Organizations, and Research and Development Centres.
- Additional interviews: Implemented with 71 key STI policy stakeholders and industrial stakeholders in China, identified and interviewed with the support of Tsinghua University and Renmin University.

The partnership between the EU and China has deepened over the years incorporating a greater number of topics. The current basis for cooperation is summed up in the EU-China 2020 Strategic Agenda for Cooperation signed in November 2013. Key areas for STI cooperation include: food, agriculture and biotechnology, sustainable urbanisation, aviation, water, and ICT, among others.

EU-China Cooperation is being implemented via increasing access to each other's funding programmes as well as by providing funding for personnel involved in joint projects in these strategic areas from each side via specific programmes such as the China-EU Science and Technology Cooperation Special Program funding Chinese researchers in joint projects or the EU-China Research and Innovation Partnership (ECRIP) funding mobility of EU Researchers to China.

China´s approach to international STI collaboration takes on many forms - from joint academic research to technology transfer and licensing, Foreign Direct Investment (FDI), mergers and acquisitions – which enable it to be connected to various sources of expertise. Joint Ventures were found to be one of the main forms for Chinese companies (SOEs in particular) to promote international research/innovation cooperation and to access foreign technology, funding, management and marketing expertise. Joint research centres, programmes and research networks were also found to be popular forms of academic collaboration.

The main guiding policy for Science, Technology and Innovation is the Medium and Long Term S&T Development Plan 2006-2020, whose goals are further detailed in five year plans, such as the current Twelfth Five -Year-Plan for Science and Technology Development. These policies show an increasing focus on STI as a means to address societal challenges as well as a focus on building up indigenous innovation by improving university-industry links, attracting overseas talent, enhancing intellectual property rights protection, and strengthening international cooperation.

There are also policies specifically addressing issues with certain regions, such as the Revitalization Plan for Higher Education Institutes in Mid- and Western China (2012-2020), which aims to tackle disparities between the more developed coastal and the less developed Central /Western regions. On the other hand, more developed regions are being used to test new policies. For example, the Framework for Development and Reform Planning for the Pearl River Delta Region (2008-2020) aims to upgrade existing low-end manufacturing and stimulating modern service industries testing a more open innovation system based on innovation platforms.

The main issues that are currently being addressed by STI policy in China include weak research–industry linkages; increasing enforcement of intellectual property rights laws; insufficiencies in the evaluation of government R&D expenditures at certain levels; progress in expanding basic research; and improving coordination of government agencies responsible for STI.

The major funding agencies are the Ministry of Science and Technology (MoST), the National Natural Science Foundation of China (NSFC), and the China Scholarship Council (CSC) affiliated to the Ministry of Education (MoE). The Chinese Academy of Sciences (CAS) also has programmes to support the researchers at its institutions in R&D activities including international collaboration. In addition, there are also several regional agencies providing funds to support science and technology. Examples of major agencies include Beijing Municipal Commission of Science and Technology (BMCST), the Science and Technology Commission of Shanghai Municipality (STCSM) and Guangdong Provincial Department of Science & Technology (GPDST). Each of these agencies has programmes dedicated to international cooperation. In spite of increasing support for international R&D cooperation, several challenges remain for participation of EU researchers in certain programmes, according to evidence gathered in this study, including: difficulty in accessing information on funding opportunities; procedural issues for application; lower funding for projects under Chinese funding programmes compared to that for EU projects; and lack of transparency in selection procedures.

Regarding support to innovation in companies, it is important to highlight the Innovation Fund for Small Technology-based Firms – InnoFund, and the availability of tax incentives for high-tech and new-tech enterprises located in specific areas such as Science parks. Beyond this, banks are increasingly lending to SMEs, but financing of innovation activities and new ventures by banks is only in its early stages. The government has begun to see venture capital (VC) as essential to encouraging indigenous innovation and is a major contributor as well as recently implementing several reforms that facilitate exit strategies. However, evidence gathered in this study indicates that risks are believed to be high for investors and there is still a lack of capital to support entrepreneurs, particularly for early-stage investment. Angel investment is growing but still scarce in China.

Industrial policy documents supporting STI, include the Development Plan of National Strategic Emerging Industries (2011-2015) to foster knowledge intensive industries such as Information Communication Technologies (ICT) and biotechnology and five year plans for specific industrial sectors such as those for environmental protection, waste recycling technology, solar power development or for the bio-industries. There is also a National Plan for Building Indigenous Innovation Capabilities (2011-2015), which contains a number of measures to reduce the country's dependence on foreign technology, aiming at promoting Chinese-owned technology and intellectual property. This has been viewed by foreign firms as a means to limit their business opportunities in China's economy.

In order to implement the indigenous innovation policy, Chinese governmental organizations at the central and local level have issued an indigenous innovation catalogue and procurement policies to give preference to certified indigenous innovation products. They have also introduced incentives such as financing and tax relief schemes to encourage the development and use of indigenous innovation products by Chinese companies.

According to information gathered in this study, Chinese government policies related to public procurement present several challenges to foreign companies, including difficulties with accessing information particularly due to the decentralization of this process as well as a lack of transparency.

Outsourcing to universities/ CAS institutes was identified as one of the most common means for Chinese companies dealing with STI. Also, companies often import technology. Involvement of EU organizations in the provision of solutions for Chinese industry may provide opportunities for mutual

benefit, however, a number of those interviewed in this study considered it essential to have the support of intermediary agencies in this process.

Human resources policies supporting STI include the Medium and Long-term Talent Development Plan (2010-2020) and the Medium- and Long-term Educational Reform and Development (2010-2020). Both policies aim to encourage greater innovation and entrepreneurship whether among students or by attracting overseas talent. Educational reforms include promoting more intense cooperation between companies and the vocational education sector, and measures to address skills shortages in certain areas including demand forecasting.

A number of funding programmes are addressing STI human resources development including those administered by MoST, NSFC, and CSC. CAS also possesses a number of programmes funding the development of human resources at its institutes. The Yangtze River Scholar Award Scheme of the Ministry of Education has been newly updated to support the implementation of the above mentioned human resources policies to develop STI human resources.

The quality of higher education has been reported to have improved immensely. However, there has been an uneven geographic distribution of talent across the country. 'Returnees', that is Chinese researchers returning to China from abroad, are seen as an important source of knowledge and a number of programmes have been introduced to attract them.

Policies to improve research and technology infrastructure include the National Medium and Long-term Plan for Building Key S&T Infrastructure (2012 - 2030), the 12th Five-year Plan for National High-tech Parks & the 12th Five-year Plan for National High-tech Business incubators (2011-2015). New major infrastructures are planned in seven strategic areas: energy, life science, earth system and environment, materials, particle physics and nuclear physics, space and astronomy, and engineering technology, which will be open to outside users. China has also planned to accelerate the development of high-tech parks, clusters and incubators increasing their innovation support capacity and prioritising strategic emerging industries as well as the service sector. Recently the western part of China has also become a popular place for SME clusters, with the government highlighting development in the region.

The "open door" policy in China has enabled easier access to foreign capital and technologies and spurred its knowledge-intensive activities. China is now an important research, development and

innovation (R&DI) partner with many countries and organizations around the world. This has led to the large majority of European Member State governments as well as many institutes in Europe to establish concrete science and technology cooperation activities with China such as joint R&D programmes, joint R&D centres or joint PhD programmes.

Regarding the development of firms, whilst there are some tax incentives for R&D intensive companies located in high-tech zones, foreign companies, and in particular SMEs, face certain challenges including: access to finance; restrictions on representative offices; access to information about regulations; and difficulties in maintaining human resources. Additionally, compulsory technology transfer may be required for those entering Joint Ventures.

China has made substantial progress in recent years with respect to Intellectual Property Rights (IPR) protection, establishing anti-piracy and anti-counterfeiting laws and regulations as well as conducting a "Special Campaign" to improve enforcement. The third revision of patent law came into force in 2011 and efforts have been made to improve skills in the intellectual property professions. Yearly plans developed by the State Intellectual Property Office (SIPO) set out the priorities for each year in this area. SIPO is keen to cooperate with other countries for the development of IPR in China. Dialogue between the EU and China on IP issues has taken place since 2003. A new joint project has just begun including: EU-China Customs cooperation on IPR; and exchanges on legal and administrative IP issues - best practices, assistance in drafting IP law revisions and implementing regulations as well as the compilation and publication of databases on IPR issues. The interviewees questioned in this study confirmed the government efforts in this area and considered that these measures have brought positive achievements recognized by the international community. Whilst challenges for foreign companies still exist (particularly including access to information), it was generally felt that the situation was improving and at the same time foreign companies were developing strategies for dealing with this situation.

Standardization is another area that has seen rapid development in China in recent years. Chinese standard development is based on a top down approach. The strategy appears to be to use standardization as a way to promote indigenous innovation, while also participating in international standards setting, aiming to promote Chinese standards in this context. This study has found evidence that this creation of national standards to compete with international ones, can be viewed as a barrier to market access, forcing foreign firms to adopt Chinese technologies so that they can do business in

China. It is also thought to inhibit transfer of technology to China. However, since China faces difficulties in competing against developed countries whose standards require acquisition of expensive IPR, the development of its own standards represents a strategy to overcome these difficulties and compete alongside developed countries by reducing exposure to royalties. International cooperation in this area is active. Increasing EU-China collaboration is evidenced by the establishment of the Europe-China Standardization Information Platform (CESIP).

WP5: Draw conclusions for the EU as regard the challenges and opportunities provided by the development of China the short and medium term (5 years)

The objective of WP5 was to draw conclusions on challenges and opportunities brought about by the development of China and provide the information to guide the decision making process in the context of an EU (and its Member States) /China STI strategy. These mainly concerned:

- Thematic areas of common interest;
- Challenges and opportunities for EU higher education and research establishments;
- Challenges and opportunities for industrial stakeholders;
- Recommendations for improving the EU's understanding on China's STI.

Thematic areas of common interest

Following the EU-China 2020 Strategic Agenda for Cooperation topics for STI, this study analysed: Food, agriculture, biotechnologies (FAB); sustainable urbanisation; aviation and aeronautics; and ICT.

For FAB, important factors stimulating and identifying opportunities for collaboration include: the EU-China flagship initiative for research and innovation in FAB, the Chinese Agricultural Science and Technology Innovation Programme (ASTIP) and an increasing focus on the Green Economy. Challenges concern: mechanisms for co-funding; information access on joint opportunities; market entry barriers for bio-based products; and IPR concerns (given the EU's leading position in this area).

It is recommended to explore the use of the SME Instrument (e.g. phase 3) to help encourage European SMEs to enter the Chinese market; to continue support for structures that can raise awareness of funding opportunities; to foster dialogue between the EU-China Flagship initiative for research and innovation in FAB and (e.g.) China-EU Water Platform to encourage mutual learning and exchange; and for EU policy makers to continue to advocate the removal of bio-based product market

entry barriers e.g. green public procurement, and legislation that promotes market growth, addressing standards or labelling claims.

In the area of sustainable urbanisation, the EU China Partnership on Urbanisation as well as collaborative activities in sustainable energies are fostering collaboration opportunities. Challenges were identified regarding the need for reciprocal knowledge on urbanization processes; the requirement for compatible standards in urban transport; and the necessity to develop interactions with a range of local and regional authorities. It is thus recommended to foster dialogue between the different collaborative activities related to this area (e.g. Smart Cities, EU-China collaboration in the area of sustainable energy); build networks of relevant actors and mechanisms of dialogue between sectors; and continue work towards the removal of market entry barriers e.g. in public procurement and legislation promoting energy efficiency.

For aviation and aeronautics, the EU-China Civil Aviation Project (EUCCAP) has promoted opportunities for collaboration and China's aviation industry growth is creating demand for innovation, which in turn is likely to create opportunities for STI activities with and in China. However, the EU CCC Position Paper 2013/2014 identified market barriers including restrictions in the area of licensing that negatively affect the involvement of foreign companies in this sector and recommends strengthening of dialogue in this area including the establishment of regular strategic-level aviation dialogue between the European Union and China. This study also recommends continued work to reduce the market barriers in this area.

In the area of ICT, the OpenChina-ICT and now the CHOICE and EU FIRE projects have been strengthening the collaboration. EU-China Expert Groups also exist for future internet and Internet of Things (IoT) smart cities and broadband policy. Electrical and optical equipment is one of China's strongest sectors, thus while competition is fierce, collaboration is important to overcome challenges such as a lack of a common technology architecture and standards as well as interoperability issues and concerns about internet governance, security and differing privacy policies. Smart City collaboration is recommended to establish knowledge exchange platforms and help strengthen the link between cities and enterprises.

Higher education and research establishments

The study's conclusions in regard of higher education and research establishments are presented by comparing the opportunities and challenges associated with different cooperation strategies such as:

- Human capital movements;
- Establishing joint research centres.

Human capital movements

Increasing funding opportunities are promoting the exchange of personnel between the EU and China. However, some challenges remain. For example, this study has identified evidence that Chinese research institutions can encounter difficulties in promoting themselves internationally. It was also noted that there is still some lack of knowledge about China and of the quality of its research system among European researchers. The high bureaucracy of the Chinese research system is also believed to pose a challenge. In order to improve the environment for collaborative activities and maximise their benefits, it is recommended to emphasize reciprocity of human capital movements to maximize access to contacts with China. This can perhaps be achieved by introducing a requirement/ incentive for Chinese researchers returning to China after a period in the EU to continue collaboration with their EU counterpart researchers. Alternatively, a Chinese alumni network targeting specific research areas could be developed to encourage Chinese researchers returning from Europe in continuing collaborative activities or even for EU researchers returning from China.

Establishing joint research centres

Establishing joint research centres can create favourable conditions for collaborative activities, providing a continuous mechanism for sharing research facilities and knowledge facilitating access to local incentives. Challenges associated with this mechanism of cooperation include difficulties in aligning different academic systems, among others. Also, it requires the allocation of a greater level of investment than less permanent collaborative activities. Thus strengthening of EU support for the implementation of joint research structures in China is recommended to help increase EU access to relevant data, research funding, facilities and talent in China, emphasizing EU SME Centre services.

Industrial stakeholders

The study examined challenges and opportunities for industrial stakeholders including SMEs and makes recommendations for:

- Industry-research collaboration;

- Physical infrastructure for industry cooperation.

Industry-research collaboration

There are an increasing number of foreign-invested R&D centres in China and clusters have become a hub for (Chinese and EU) researchers to seek cooperation with industry providing opportunities for industry-research collaboration. The large gap between industry and research presents a challenge for cooperation and the Investment Catalogue may act as a domestic protection mechanism. However, the demand for technology and EU organizations' ability to provide innovative solutions that address industry leads to the recommendation to strengthen the use of the EU SME Centre in Beijing to improve connections between EU firms with Chinese research and industry stakeholders and to continue to push for the opening of some specific sectors of the Investment Catalogue.

Physical infrastructure for industry cooperation

Incubators and science parks play an increasing role in the promotion of innovation clusters, technology transfer and commercialization of research results in China. Further, the previously mentioned Innofund, for example, helps to subsidize equipment upgrades for specific purposes, such as energy saving, emission reduction, and the adoption of new generation technologies. However, access to R&D infrastructure in China remains difficult for EU companies and joint R&D centres with companies are still immature in Chinese universities. It is therefore recommended to increase role of the EU SME Centre in Beijing in clustering initiatives being developed in China.

Recommendations for improving the EU's understanding on China's STI

Since up-dating the data related to the indicators can be done more efficiently than collecting it for the first time, it is recommended that the European Commission comes to a structured agreement for a period of a few years to do an up-date of a given basic list of indicators, for which international comparison is possible and to show the trends in time. Concerning publications, the data is always available, that is: it can be retrieved from the Scopus database at any time by anybody, but here again it is less time-consuming when the up-dating is organized in a structured way and at pre-set moments in time (e.g. same month in the year). Proposals for such structured agreements should be discussed with others who are engaged in data-gathering activities such as the OECD and Eurostat, in order to avoid duplication and in order to agree on the specifics in terms of method and definitions of the indicators and for instance the aggregation level of the fields of publication concerning the bibliometric data.

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1. Introduction

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More specifically, the study had the following goals:

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- Pinpointing opportunities and challenges brought about by the STI development of China.

In order to achieve the goals, the key methods utilized in the study include bibliometric research, desk research, interviews, survey questionnaires, workshops, and analysis of existing data and literature.

The study was implemented by the consortium of Sociedade Portuguesa de Inovação (SPI), The United Nations University - Maastricht Economic and Social Research and Training Centre on Innovation and Technology (UNU-MERIT), and the Austrian Institute of Technology (AIT).

Sociedade Portuguesa de Inovação (SPI) (http://www.spieurope.eu/)

SPI is an International Management Consultancy Company founded in 1997 as an active centre of national and international networks connected to the science, technology and business innovation sector. SPI is the coordinator of the study, as well as leader of WP3: Assessing China's policies in terms of development of its domestic STI capabilities and its international strategy and WP4: An overview of framework conditions and the development and growth of innovative firms.

The United Nations University - Maastricht Economic and Social Research and Training Centre on Innovation and Technology (UNU-MERIT) (http://www.merit.unu.edu/)

UNU-MERIT is a research and training centre of Maastricht University and United Nations University, focusing on the role of STI in the broadest sense in bringing about development and the improvement of social welfare at the national and international level. MERIT is leader of WP1: Identifying, assessing and updating data and indicators relevant to STI in China.

Austrian Institute of Technology (AIT) (http://www.ait.ac.at/)

AIT is one of the largest technical research centres in Austria. The AIT Foresight and Policy Development has expertise in the emergence of new technologies, as well as economic, societal and environmental impacts. AIT leads WP2: Mapping of China's research and innovation capabilities in selected technologies

1.1. Objectives of the report

The report presents the results and analysis developed by the consortium on the STI Performance of Mainland China (excluding Hong Kong and Macau) and is organised in the following sections:

- **Section 2 - Measuring China's STI development:** This section identifies, assesses and updates data and indicators relevant to STI in China and presents new findings including those related to RTD, economic performance and research output.
- **Section 3 - Mapping of China's research and innovation capabilities in selected technologies:** This section presents the mapping of China's research and innovation capabilities in selected technologies including China's industrial structure in comparison (as an introduction); China's overall RDI performance and the sectorial specialisation of business R&D in China.
- **Section 4 - China's STI policies and international strategy:** This section provides an overview of current features of STI policies and the likely prospects for the future. Other features of China's innovation system including the situation with regard to industrial and indigenous innovation including its impact on foreign firms, human capital, and STI infrastructure are discussed. International cooperation strategy is reviewed and patterns of international cooperation are assessed.
- **Section 5 - Framework conditions for STI in China:** This section provides an overview of the Framework conditions for STI in China system and of the consequences for innovative operators in China. In particular, the following themes are included: development of firms;

public procurement; the role of the "investment catalogue"; the patenting and licensing system; and the development of Chinese standards.

- **Section 6 - Conclusions and recommendations:** This section draws conclusions for the EU in regard to the challenges and opportunities provided by the development of China for the short and medium term (5 years) including: thematic areas of common interest for the EU and China; cooperation strategies for EU higher education and research establishments; and cooperation strategies for industry stakeholders including SMEs.

1.2 Methodology

The methodology for the study was provided in five WPs. This report identifies and discusses the work and analysis provided. A description of the five WPs is provided below.

WP1: Identifying, assessing and updating data and indicators relevant to Science, Technology and Innovation in China

The objective of this WP was to identify those indicators which are most relevant to measuring the overall progress of STI development in China and which are coherent with the Innovation Union Scoreboard and the Innovation Union Competitiveness Report. The results of WP1 supported WP2 in studying China's STI Performance in more detail for specific scientific disciplines, technologies and industrial sectors. The approaches taken to achieve the goals were as follows:

- Identification of relevant indicators;
- Study of relevant indicators for disciplines, technologies and industrial sectors;
- Verification, assessment and interpretation of the indicators.

WP2: Mapping of China's research and innovation capabilities in selected technologies

Using the broad overview of the indicators to measure the technological and scientific capabilities of Chinese universities and firms provided in WP1 as inputs, WP2's objective was to then provide a thorough analysis of China's Performance in science and technology. WP2 focused on an analysis of China's research and innovation capabilities.

First, a broad overview of China's research and innovation capabilities across all scientific fields, technologies and industrial sectors was conducted. Second, selected industries and cross-cutting technologies were studied. The sectoral coverage of this second stage focused on industrial sectors using the two-digit level of the *Nomenclature generale des Activites economiques dans les*

Communautes Europeennes (NACE)[5] where China is a current or future competitor for firms from the EU-27. The importance of sectors and cross-cutting technologies in light of the "grand challenges" were complimentary selection criteria. The six challenges identified by the High Level Group for Joint Programming (CREST-GPC) [6] in preparation for the EU Joint Programming Initiative include Cities/Transport, Climate Change (including Energy), Cultural heritage, Food, Water, and Health.

The WP2 approach included the following:

- Selection of the fields;
- Matching of selected sectors and cross-cutting technologies with scientific disciplines, technologies, and industrial sectors;
- Making various data sources comparable;
- Identification of relevant stakeholders and infrastructures through patent and publication data sources;
- Assessment of trends in the medium term.

WP3: Assessing China's policies in terms of development of its domestic STI capabilities and its international strategy

The objective of WP3 was to analyse and identify the main trends in policy-making and funding system for STI development in China, and to analyse China's international strategy concerning STI. This was achieved through a variety of data collection and analysis techniques, including:

- Development of a list of stakeholders in China and Europe of more than 2,000 contacts, which included representatives from the government, industry and research;
- Provision of a set of survey questionnaires for foreign research and industry stakeholders (in English) and for Chinese research and industry stakeholders (in Chinese);
- Provision of structured interviews that aim at complementing the survey questionnaire;
- Implementation of a Fact-finding mission to China (Beijing, Shanghai, Guangzhou and Shenzhen) in order to support the interview process. The mission was split into two groups of

5 Nomenclature generale des Activites economiques dans les Communautes europeennes (NACE) refers to the industrial classification as defined in Revision 1 which is used by Eurostat. NACE Rev. 1 replaced NACE 1970. In so doing it established a direct link between the European classification and the internationally recognised ISIC Rev. 3 developed under the auspices of the United Nations. These two classifications are directly compatible at the 2-digit level and more detailed levels of ISIC Rev. 3 can be calculated by aggregating the more detailed levels from NACE Rev. 1. (Source: OECD - glossary)
6 CREST GPC 1308/09, http://register.consilium.europa.eu/doc/srv?l=EN&t=PDF&gc=true&sc=false&f=ST%201308%202009%20INIT&r=http%3A%2F%2Fregister.consilium.europa.eu%2Fpd%2Fen%2F09%2Fst01%2Fst01308.en09.pdf

two experts (including at least one Chinese expert) to interview the key stakeholders and collect information from other sources.

WP4: An overview of framework conditions and the development and growth of innovative firms

The objective of WP4 was to provide an overview of the Chinese innovation system and of the consequences for innovative operators in China. The WP method included:

- Desk research on the different topics of the Chinese STI system for development of innovation in firms;
- Additional interviews to those conducted in WP3. The result of the desk research helped to serve as a basis for these interviews with key stakeholder that were mostly provided during the Fact-finding mission and were with industrial representatives.

WP5 Draw conclusions for the EU as regard the challenges and opportunities provided by the development of China the short and medium term (5 years)

The objective of WP5 was to draw conclusions on challenges and opportunities brought about by the development of China and provide the information to guide the decision making process in the context of an EU (and its Member States) / China STI strategy. Additional interviews and desk research were carried out and the results of WP1-4 analysed to develop the conclusions and recommendations.

2. Measuring China's STI development

2. Measuring China's STI development

Data for China has been collected for STI indicators which are used for the Innovation Union, namely for a selection of indicators used by the Innovation Union Scoreboard (IUS 2011 and 2014) and the Innovation Union Competitiveness report (IUC 2011 and 2003). In this report, the data collected for China is presented and compared alongside the European and other national data as reported in the Innovation Union Scoreboard 2014, and the Innovation Union Competitiveness Reports (2011 and 2013). For a selection of IUC indicators the most recent available data for the EU[7] was extracted from Eurostat in 2014, in order to allow for a better EU-China comparison on those indicators. An overview of the data is given in two tables: Table 2.1 for the indicators of the IUS (sub-section 2.1) and Table 2.2 for the indicators of the IUC (sub-section 2.2). In sub-section 2.3 the research output of China is assessed based on a bibliometric analysis.

2.1. RTD indicators

This sub-section first presents data collected for China which is comparative to the indicators used in the Innovation Union Scoreboard (IUS) Report 2014 to compare Member States, and then focuses on the indicators from both the IUS and IUC concerning RTD performance for a comparison between EU and a selection of non-EU countries.

Table 1 provides the indicator values for China as well as the EU value and the value of a selection of large EU or associated countries. The reference year for the Chinese data is mostly 2011 or 2010 for the indicators on 'firm activities' which are not surveyed every year. The reference year for the EU data is also mostly 2011. For the 'firm activities' data which are based on the Community Innovation Survey, older data than 2011 has been used by the IUS for some individual European countries, e.g. for the indicator 1.1.1 'New doctorate graduates' in Table 1, for most countries 2011 data was available, but for some countries only an older reference year is available.

7 EU refers to the EU15 up to 2003, the EU25 from 2004, and the EU27 from 2007. EU28 data was not available at the time of writing.

Table 1 IUS 2014, national indicators, Chinese data compared to EU and selection of countries

IUS 2014, national indicators (EU reference year)	China	EU	DE	ES	IT	PL	RO	UK	TR	China reference year
Enablers										
1.1.1 New doctorate graduates (2011)	2.49	1.7	2.8	1.2	1.5	0.5	1.7	2.4	0.4	2011
1.1.2 Population completed tertiary education (2012)	15.2	35.8	31.9	40.1	21.7	39.1	21.8	47.1	18.0	2010
1.1.3 Youth with upper secondary level education (2012)	46	80.2	76.2	62.8	77.6	89.8	79.6	81.8	58.3	2010
1.2.3 Non-EU/domestic doctorate students (2011)	10.9	24.2	11.2	18.0	8.4	1.9	2.1	30.6	3.2	2011
1.3.2 Venture capital (2012)	0.12	0.277	0.223	0.192	0.138	0.234	0.137	0.419		2011
Firm activities										
2.1.1 Business R&D expenditure (2012)	1.4	1.31	1.95	0.68	0.69	0.33	0.12	1.14	0.37	
2.1.2 Non-R&D innovation expenditure (2010)	1.19	0.56	0.88	0.39	0.59	1.02	0.46		0.16	2004-2007
2.2.1 SMEs innovating in-house (2010)	17.5	31.8	45.2	22.1	34.8	11.3	10.8		28.2	2004-2006
2.2.2 Innovative SMEs collaborating with others (2010)	7.4	11.7	14.0	5.8	4.4	4.2	2.9	22.3	5.3	2004-2006
Outputs										
3.1.1 SMEs introducing product or process innovations (2010)	28.3	38.4	57.0	28.1	39.8	14.4	13.2	21.3	29.5	2004-2006
3.2.1 Employment in knowledge-intensive activities (2012)	14.5	13.9	15.8	11.9	13.2	9.7	6.5	17.8	5.0	2010
3.2.2 Contribution of MHT product exports to trade balance (2012)	3.2	1.3	9.2	3.3	4.8	0.6	0.4	4.2	-3.1	2012
3.2.3 Knowledge-intensive services exports (2011)	35.8	45.3	55.6	21.6	27.5	28.3	45.2	61.2	21.9	2012
3.2.4 Sales of new to market and new to firm innovations (2010)	12.7	14.4	15.5	19.0	14.9	8.0	14.3	7.3	15.8	2006
3.2.5 Licence and patent revenues from abroad (2012)	0.013	0.77	0.64	0.31	0.45	0.21	0.38	0.68	0.00	2012

Sources IUS 2014 for EU data and this study for Chinese data (see annex for details);

For the indicators in Table 1 which 'enable' innovation, most values for China were found to be below the EU value, and also below the national value for the selected countries, except for the share of new doctorate graduates. The share of population aged 30-34 having completed tertiary education was 15.2% for China in 2011. For the EU the latest value (2012) was much higher - 35.8%, but compared with Turkey (18%) and Italy (21%) the difference was smaller (Table 1). Venture capital investment as a % of GDP was at a lower level in China in 2012 (0.12 %) than in the EU as a whole (0.28%), but comparable to the level of individual EU Member States such as Italy and Romania (both at 0.14%).

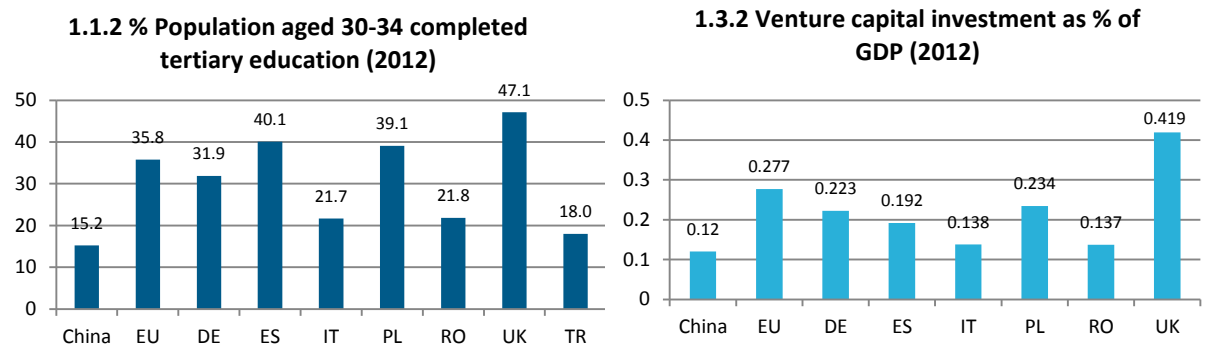

Figure 1. Human resources and venture capital, China and selection of IUS2014 European countries

Sources: IUS 2014; for China see annex (reference year 2011)

The IUS also contains an international comparison between the EU and non-EU countries, but for a more limited set of indicators. The share of people with tertiary education for the age group 25-64 (Figure 1) for China in 2011 (and 2010) was 10% and for the EU in 2011 was 28.5%. In most countries there was an increase in this high-educated share of the population, but for China, Russia and India there was no increase between 2010 and 2011.

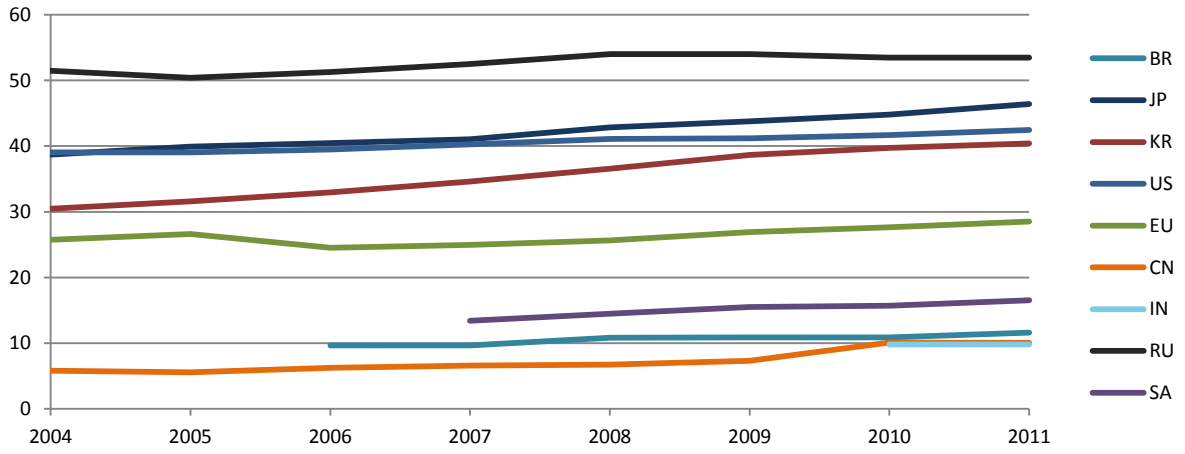

Figure 2. Percentage population aged 25-64 having completed tertiary education, 2011

Source: IUS 2014, international comparison

The IUS does not report absolute numbers, e.g. the total number of people. The IUC often reports both the relative and absolute figures. At 74 million, the number of Human Resources in Science & Technology in China in 2011 was quite close to the 98 million in the EU (Figure 3). However, the number of new S&T graduates (ISCED 5A) with Science & Engineering (S&E) orientation in 2011 was 875,000 in the EU, way below the 1.4 million in China. For China this number had increased by more than 100,000 to 1.5 million in 2012. This strong S&E orientation of China's human resources was also evident in other aspects of STI in China, and its economy and society at large.

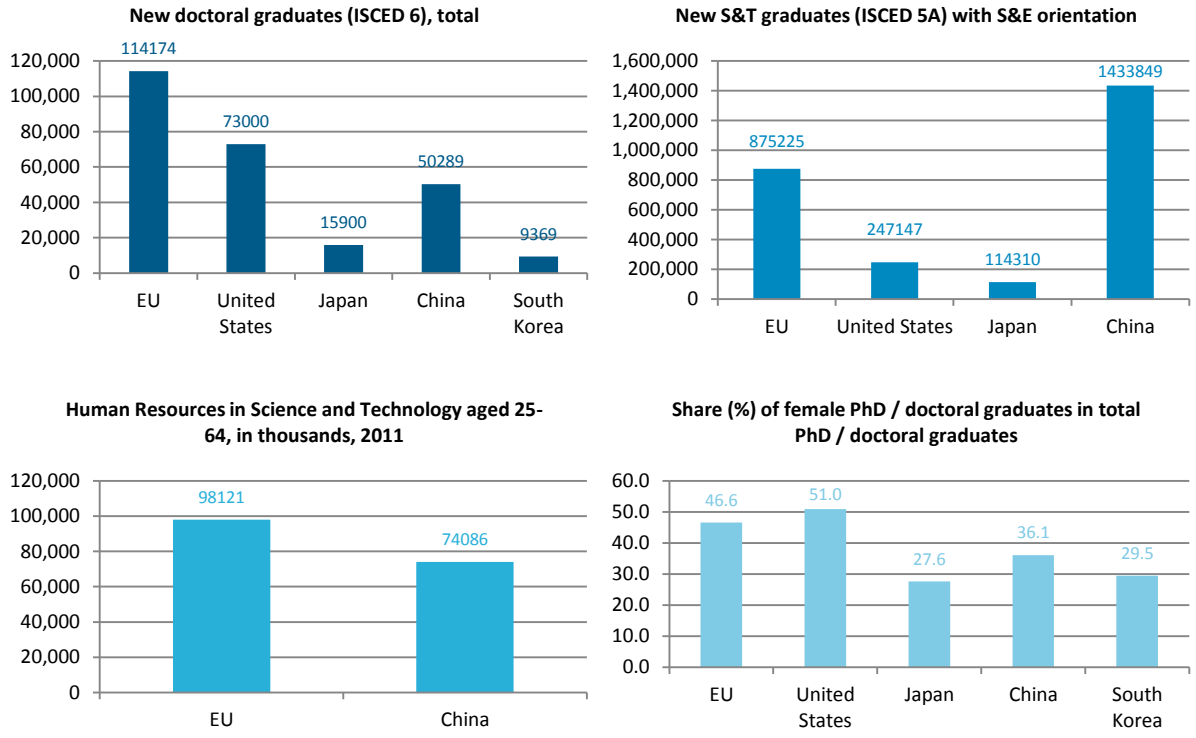

Figure 3. Human resources, EU versus China, US, Japan

Sources: Eurostat for EU (2011); for China see annex (2011); and IUC Report 2011 for US and Japan (reference year 2008)

Following the previous indicators, innovation performance of firms was also analysed. Compared to the indicators which are labelled 'enablers' in the IUS, the Chinese indicator performance for firm innovation activities, was perhaps more impressive than for the enabling factor indicators. In terms of business R&D expenditure as a share of GDP the value for China was 1.4 in 2012, above that for the EU, which was 1.3% (Figure 4). The business R&D intensity was below that of Germany, but way above that of, for Spain and Italy. Next to this high R&D intensity of the business sector, also the non-R&D

innovation expenditures of Chinese firms were clearly higher (1.19% in 2010 compared to 0.56 for the EU), and above the level of any of the selected countries, such as Germany (0.88) and the catching-up country Poland (1.02).

The share of SMEs innovating in-house was 17.5 in 2010 (Figure 4), which was below the value for the EU as a whole, but higher than that for Poland (11.3) and Romania (10.8). It must be noted that the definition of an SME in China is different to the EU definition[8], but, nonetheless, the innovation output indicator concerning SMEs introducing product or process innovations (28.3 in 2010) (Figure 4), shows that in this respect Chinese SMEs seemed to perform better than for instance those of the UK, Spain, Poland and Romania.

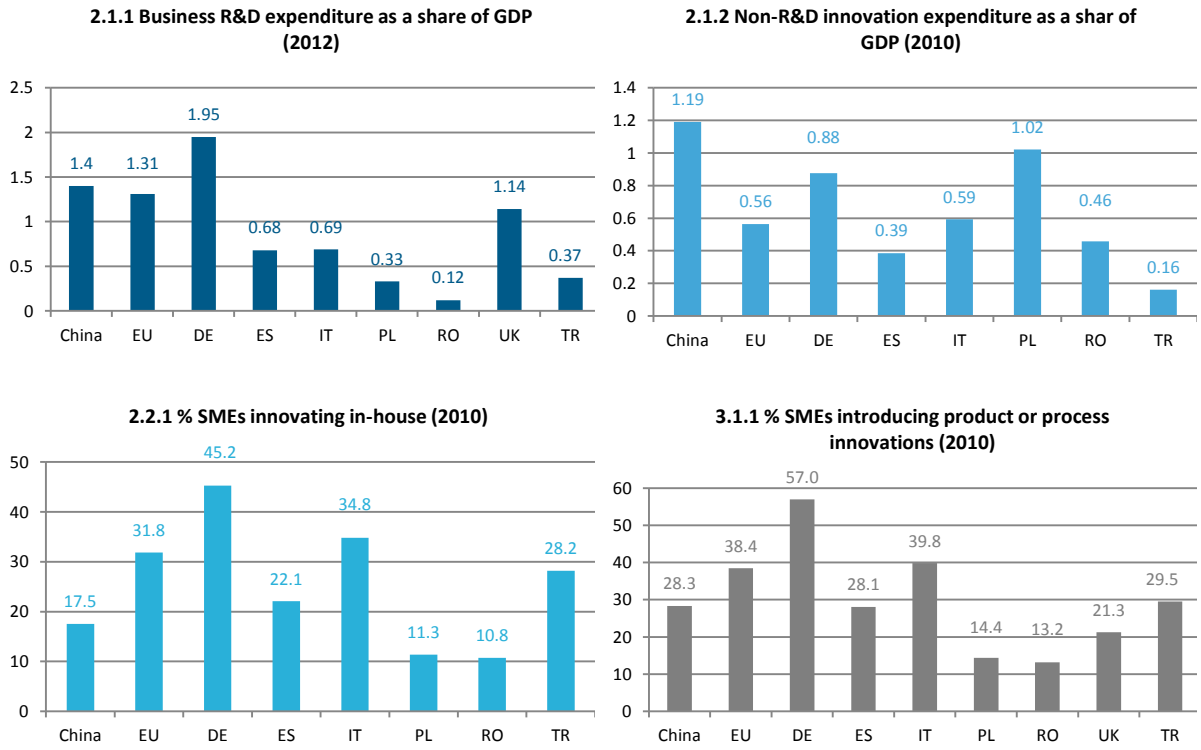

Figure 4. IUS 2014 Indicators for firm activities

Sources: IUS 2014 for EU data; for China see annex

8 In the EU an SME is defined in EU law: EU recommendation 2003/361 .The main factors determining whether a company is an SME are: 1. number of employees and 2.either turnover or balance sheet total. An SME has <250 employees. It also has either a turnover of ≤50 million € or a balance sheet total of ≤43 million €. Medium firms in China are defined as the firms employing equal to or more than 300 but less than 2000 employees. Small firms in China are defined as the firms employing equal to or more than 20 but less than 300 employees

The amount of R&D expenditure in Euro of foreign affiliates in China was below that of foreign affiliates in the EU, US, and Japan (Figure 5). For both 2010 and 2011 the value of these R&D expenditures by foreign firms was 512 million Euro. In 2012 this had decreased to 505 million Euros. Chinese SMEs (the so called small above scale enterprises) appear to be an important driver for the increased R&D expenditure. In 2011 their R&D expenditures were equal to 11,913 million Euros. According to the latest up-date for 2012 this had increased to 14,905 million (Statistical Yearbook of China).

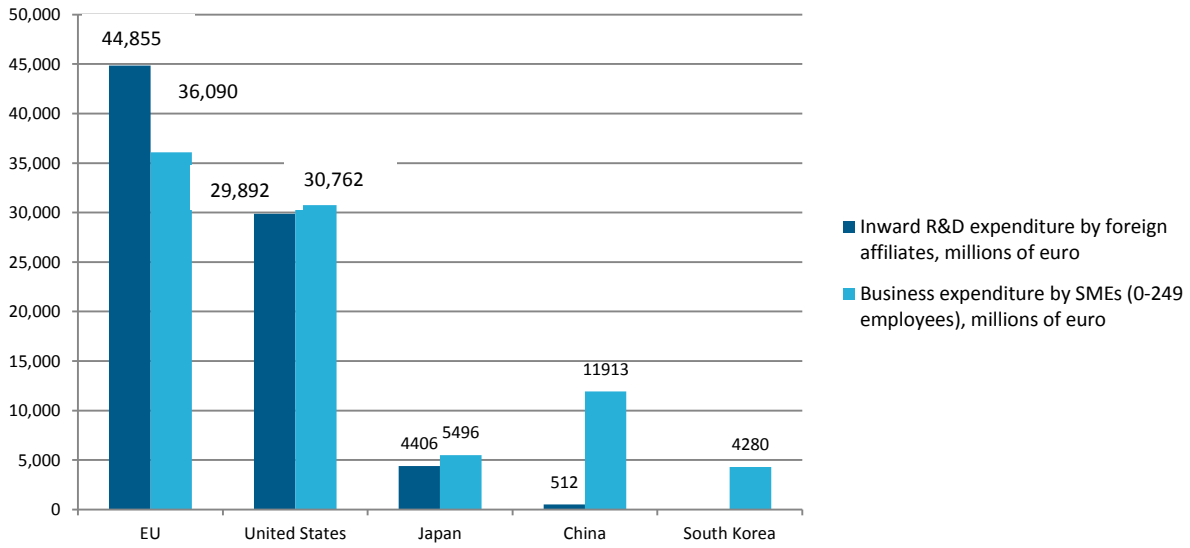

Figure 5. Business R&D expenditure by foreign affiliates and SMEs, in millions of euro

Sources: Eurostat for EU SMEs (reference year 2011); OECD for EU data for foreign affiliates (reference year 2009; for China see annex (reference year 2011); and IUC Report 2011 for US and Japan (reference year 2007)

The high business R&D expenditures in China as a % of GDP are the result of a steady increase over the last decade. The increasing trend is similar to the trend for South Korea, although for China the business R&D intensity is at a lower level (Figure 6).

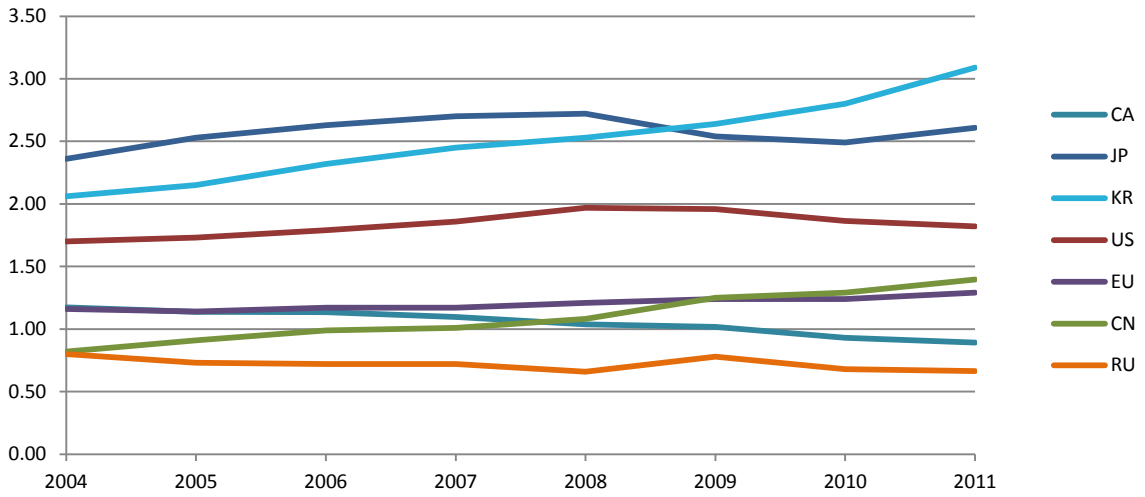

Figure 6. R&D expenditure in the business sector as % of GDP

Source: IUS 2014

The trend in R&D expenditure as a share of GDP in the public sector in China was found to differ from the trend for the business sector. The change in terms of the share in GDP did not increase much between 2004 and 2011, and between 2010 and 2011 it slightly declined. But this is in line with a global trend of a slow down after an increase between 2008 and 2009 (Figure 7).

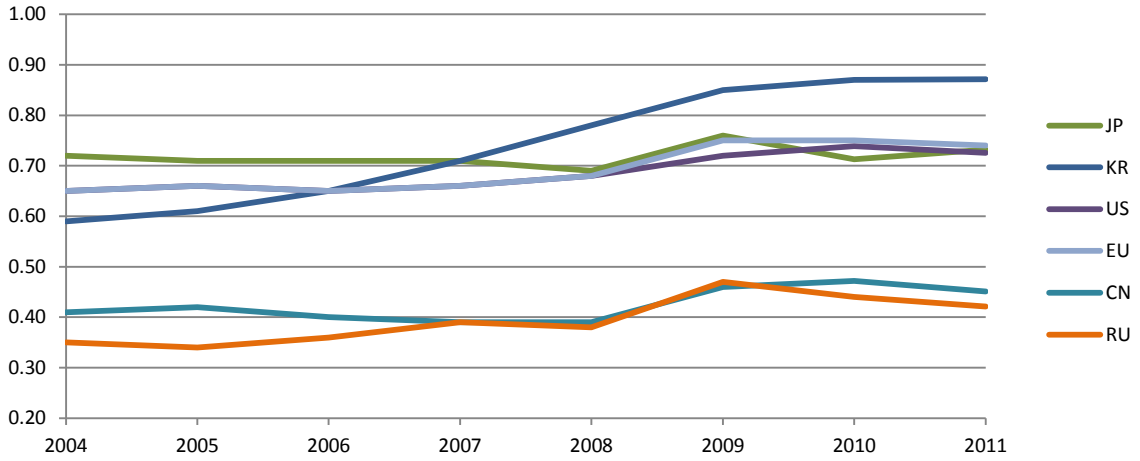

Figure 7. R&D expenditure in the public sector as % of GDP

Source: IUS 2014

2.2. Economic impact indicators

The IUS 2014 comparison between the EU and third countries shows that the economic output in terms of licence and patent revenues from abroad as a share of GDP has remained low for China, compared to the US and the EU (Figure 8), but it should be noted that for the EU the revenues from other EU Member States are also included.

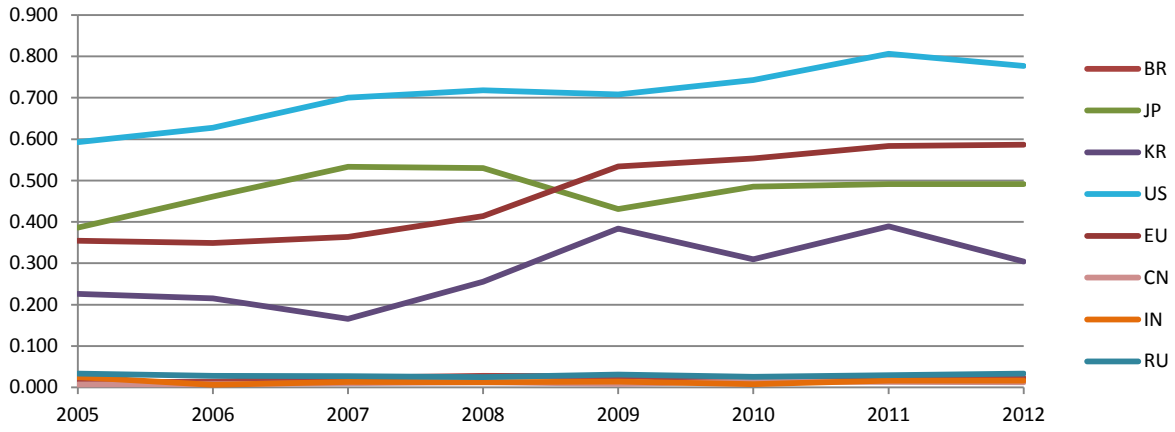

Figure 8. License and patent revenues from abroad as % of GDP

Source: IUS 2014

Knowledge-intensive services exports as a % of total services exports have increased for China between 2004 and 2008, but did not increase between 2008 and 2011 (Figure 9).

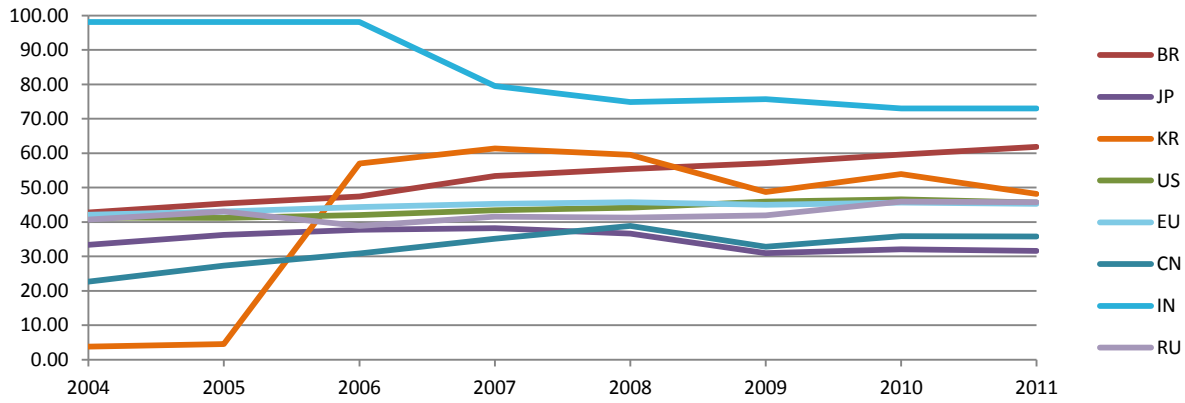

Figure 9. Knowledge-intensive services exports as % total service exports

Source: IUS 2014

Concerning the contribution of medium- and high-tech product exports to the trade balance there has been a steady increase from 2006 to 2011 (Figure 10).

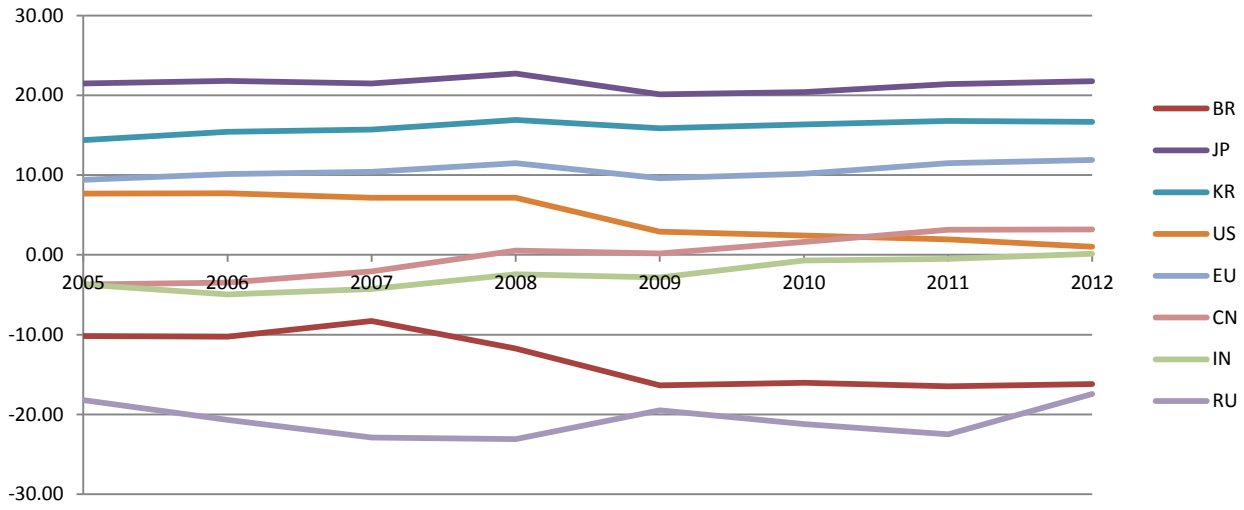

Figure 10. Contribution of medium and high-tech product exports to the trade balance

Source: IUS 2014

Table 2. Innovation Union Competitiveness Report 2011 indicators, with updates in bold for China and EU

Based on IUC Report 2011 Summary table of indicators With up-dates in bold	**EU**		**United States**		**Japan**		**China**		**South Korea**	
Gross domestic expenditure on R&D (GERD) millions of euro	236,553	(1)	270,733	(2)	113,986	(2)	45,151	(2)	21,480	(2)
R&D intensity	2.01	(1)	2.77	(2)	3.44	(2)	1.54	(2)	3.37	(2)
Business expenditure on R&D (BERD) millions of euro	146,905	(1)	196,563	(2)	89,436	(2)	33,077	(2)	16,188	(2)
Business expenditure on R&D (BERD) as % of GDP [15]	1.25	(1)	2.01	(2)	2.70	(2)	1.12	(2)	2.54	(2)
Business expenditure by SMEs (0-249 employees), millions of euro [4]	**36,090**	(0)	30,762	(3)	5496	(3)	***11,913***	(0)	4280	(3)
Business expenditure by SMEs (0-249 employees) as % of GDP	**0.29**	(0)	0.30	(3)	0.17	(3)	**0.2**	(0)	0.56	(3)
Inward R&D expenditure by foreign affiliates, millions of euro [5]	**44,855**	(1)	29,892	(3)	4406	(3)	**512**	(0)	:	
Inward R&D expenditure as % of R&D expenditure by business enterprise [5]	**32.4**	(1)	14.3	(2)	5.1	(3)	**0.83**	(0)	:	
Public expenditure on R&D (GOVERD + HERD) millions of euro	87,275	(1)	63,495	(2)	12,073	(2)	22,758	(2)	4984	(2)
Public expenditure on R&D (GOVERD + HERD) as % of GDP	0.74	(1)	0.65	(2)	0.69	(2)	0.41	(2)	0.78	(2)
Investment in knowledge (R&D and Education), millions of euro	**885,072**	(1a)	930,935	(3)	240,224	(3)	**361,737**	(0)	74,444	(3)
Investment in knowledge (R&D and Education) as % of GDP	**7.2**	(1a)	9.1	(3)	7.5	(3)	**6.95**	(0)	9.7	(3)
New doctoral graduates (ISCED 6), total	**114,174**	(0)	63,712	(2)	16,296	(2)	**50,289**	(0)	9369	(2)
New doctoral graduates (ISCED 6) per thousand population aged 25-34	**1.70**	(0)	1.56	(2)	0.98	(2)	**2.49**	(0)	1.19	(2)
Number of researchers (FTE)	150,4575	(2)	141,2639	(3)	656,676	(2)	1,592,420	(2)	236,137	(2)
Number of researchers (FTE), per thousand labour force	6.3	(2)	9.2	(3)	10.3	(2)	2.0	(2)	9.7	(2)
Number of researchers (FTE) working in the private sector	707,534	(2)	1,130,500	(3)	501,077	(2)	1,092,213	(2)	18,5811	(2)
Number of researchers (FTE) working in the public sector	797,040	(2)	282,139	(3)	155,599	(2)	500,207	(2)	50,326	(2)
Human Resources in Science and Technology aged 25-64	**98,121**	(0)	:		:		**74,086**	(1a)	:	
Human Resources in Science and Technology aged 25-64 as % of labour force	**42.4**	(0)	:		:		**9.7**	(1a)	:	
New S&T graduates (ISCED 5A) with S&E orientation) [11]	**875,225**	(0)	247,147	(2)	114,310	(2)	**1,433,849**	(0)	:	
License and patent revenues from abroad, millions of euro [6]	25,137	(1)	62,279	(2)	17,474	(2)	**568**	(0)	:	

License and patent revenues from abroad as % GDP [6]	0.21	(1)	0.64	(2)	0.53	(2)	**0.013**	(0)	:	
Community trademarks	60,967	(2)	12,877	(2)	2081	(2)	811	(2)	:	
Community trademarks per billion GDP (PPS€)	4.88	(2)	1.16	(2)	0.62	(2)	0.13	(2)	:	
Total number of scientific publications (fractional counting method)	469,479	(2)	357,837	(2)	92,089	(2)	256,495	(2)	39,792	(2)
Scientific publications in the 10% most cited scientific publications worldwide	55,557	(3)	58,319	(3)	8122	(3)	14,499	(3)	3231	(3)
Scientific publications in the 10% most cited scientific publications worldwide as % of total scientific publications of the country	11.6	(3)	15.3	(3)	8.3	(3)	7.0	(3)	8.5	(3)
PCT patent applications, total number	49,545	(3)	49,282	(3)	28,970	(3)	6416	(3)	7227	(3)
PCT patent applications per billion GDP (PPS€)	4.0	(3)	4.3	(3)	8.3	(3)	1.1	(3)	7.0	(3)
Female PhD / doctoral graduates, total number	**53,609**	(0)	32,497	(2)	4499	(2)	**98,007**	(0)(12)	2763	(2)
Share (%) of female PhD / doctoral graduates in total PhD / doctoral graduates	**46.6**	(0)	51.0	(2)	27.6	(2)	**36.1**	(0)	29.5	(2)
International scientific co-publications, total number	132,412	(2)	117,794	(2)	24,064	(2)	37,524	(2)	:	
International co-publications as % of total publications	24.2	(2)	27.4	(2)	22.6	(2)	13.5	(2)	:	
PCT patent applications with co-inventor(s) located abroad	4719	(2)	5002	(2)	627	(2)	760	(2)	261	(2)
PCT applications with co-inventors located abroad, as % of total PCT patent applications	9.7	(2)	11.1	(2)	2.3	(2)	10.5	(2)	3.6	(2)
Public-private co-publications per million population	36.2	(3)	70.2	(3)	56.3	(3)	1.2	(3)	:	
Venture capital (early stage, expansion and replacement), millions of euro [7]	10,185	(1)	12,954		:		**6773**	(0)	:	
Venture capital (early stage, expansion and replacement) as % of GDP [7]	0.09	(1)	0.13		:		:		:	
Cost of patent application and maintenance for SMEs, PPS€	167,798	(1)	4413		6953		**14,709**	(0)	5509	
Cost of patent application and maintenance for SMEs, per billion GDP (PPS€)	14.21	(1)	0.39		2.24		**1.88**	(0)	5.08	
Health technology patents (PCT)	6798	(3)	10,154	(3)	2277	(3)	540	(3)	449	(3)
Health technology patents (PCT) per billion GDP (PPS€)	0.55	(3)	0.89	(3)	0.65	(3)	0.09	(3)	0.44	(3)
Climate change mitigation patents (PCT)	1195	(3)	551	(3)	744	(3)	115	(3)	89	(3)
Climate change mitigation patents (PCT) per billion GDP (PPS€)	0.10	(3)	0.05	(3)	0.21	(3)	0.02	(3)	0.09	(3)
Employment in knowledge intensive economic activities [8] as % of total employment	35.1		:		:		:		:	

Medium and high-tech manufacturing exports, millions of euro [9]	781,149	(2)	522,413	(2)	396,343	(2)	544,786	(2)	204,299	(2)
Medium and high-tech manufacturing exports as % of total product exports [9]	59.6	(2)	59.1	(2)	74.6	(2)	56.0	(2)	71.2	(2)
Knowledge intensive service exports, millions of euro [9]	608,223	(2)	153,865	(2)	34,418	(2)	38841	(2)	35,703	(2)
Knowledge intensive service exports as %¨of total service exports [9]	49.4	(2)	41.4	(2)	33.9	(2)	38.8	(2)	69.1	(2)
Contribution of medium-high and high-tech exports to the manufacturing trade balance as % of total manufacturing [10]	5.1	(2)	5.4	(2)	12.2	(2)	:		3.5	(2)

Source: DG Research and Innovation; In bold an up-date from Eurostat for 2011 EU data; this study for 2010 and 2011 data for China (also in bold)
Notes: (0) 2011. (1a) 2010. (1) 2009. (2) 2008. (3) 2007. (4) EU does not include IE. (5) EU does not include not included 2009: BG, DK, EE, LT, LU, LV, MT, PT, RO, SK (6) EU refers to extra-EU. (7) EU does not include BG, EE, CY, LV, LT, LU, MT, SI, SK. (8) Employment in the public sector is included. (9) EU includes intra-EU exports. (10) EU does not include BG, CY, LV, LT, MT, RO. (11) ISCED 5A including first and second degree of 5A. (12) China data refers to enrolment

2.3. Research output indicators: bibliometrics

Research Output of China

Scientific output is a key aspect in evaluating China's research capacity. In this section the results of an analysis of publication data from Elsevier's Scopus are presented. The selected publication document type was "articles", which does not include conference papers, editorials, notes, reviews, etc. The time span covered the 14 most recent years: 2000 – 2013. Besides the aggregate performance, 27 disciplines were analysed using the pre-defined subject categories from Scopus.

The number of scientific publications with Chinese addresses maintained a 17% annual growth rate between 2000 and 2013, increasing from around 41,000 to over 300,000 (Figure 11). Despite the fact that the number of scientific publications for the EU and US both kept growing at a speed of 4% per year, their shares in the worldwide total have decreased over the years, both dropping 2 or 3 per cent – the EU27 from 33% to 31% and the US from 26% to 23%. The share of Japanese publications declined even more, from 9% in 2000 to 5% in 2013. The proportional shrink in the share of these countries is mainly caused by the rapid increase of BRIC countries, among which China grew the most, from 4% of the world total in 2000 to 18% in 2013. Other BRIC countries like India and Brazil have increased their shares slightly, by about 2% over the 14 years studied. Russia, however, was the only exception among the BRICs. It's share dropped by 1%, from 3% in the year to 2% by 2013.

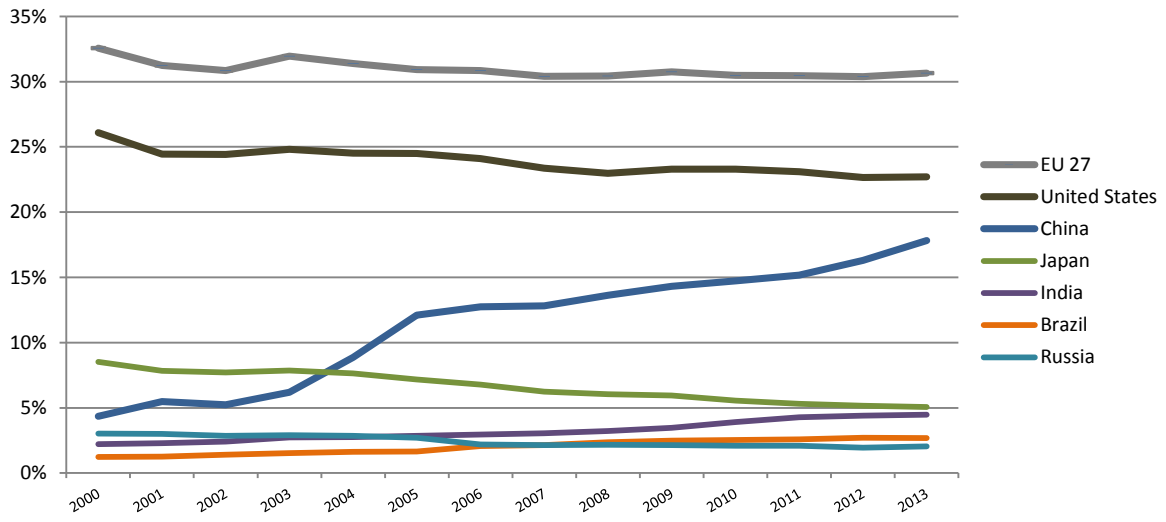

Figure 11. Publication shares in the worldwide total 2000-2013 (BRIC countries, EU[9], United States and Japan)

Source: Scopus - SciVerse Elsevier. Note: Document type is "article".

9 EU refers to the EU15 up to 2003, the EU25 from 2004, and the EU27 from 2007. EU28 data was not available at the time of writing.

Research output by field

In mapping China's research capacities, it is necessary to focus on the key scientific disciplines. To ensure comparability with other studies, the predefined subject categories from Scopus were used. The criterion in selecting key scientific fields was a combination of three areas: strong, fast growing and matching of grand challenges. The strongest research areas in China represent its scientific strengths and competitiveness in the past, while the fastest growing ones may indicate China's future development trends.

The coverage of the scientific fields consisted of two layers. Firstly, in the following section the general developing trends of 12 fields were examined, providing the publication number and the growth rate for each of these fields in the selected years (2000, 2005, 2010 and 2011). These Chinese indicators are compared with the worldwide benchmarks. The twelve fields, as agreed with the EC, were as follows:

- Computer science;
- Biochemistry;
- Engineering;
- Physics and Astronomy;
- Chemistry;
- Materials Science;
- Immunology and Microbiology;
- Environmental Science;
- Agricultural and Biological Science;
- Medicine;
- Pharmacology, Toxicology and Pharmaceutics;
- Energy.

Secondly, the text that follows presents a deeper analysis on the research efforts between China and the EU[10] in six selected fields. The selected areas were *Chemistry, Computer science, Environmental science, Medicine, Pharmacology, Toxicology and Pharmaceutics, Physics and Astronomy.*

10 EU refers to the EU15 up to 2003, the EU25 from 2004, and the EU27 from 2007. EU28 data was not available at the time of writing.

Strongest research fields

The research output in China was found to have a different pattern from that of the global output seen in Figure 12. Over the 14 year period (2000-2013), the aggregate worldwide scientific output was dominated by Medicine, which accounted for 28% of the total publications. The second field was Biochemistry, genetics and molecular biology, which was followed by Engineering and Physics and astronomy. In China, however, the dominant position – which accounted for about 29% of the national total publications – was occupied by Engineering. The next three largest fields with the most publications were Physics and Astronomy, Material science, and Chemistry. In general, the major contribution to China's total scientific research output came from hard science. On the contrary, research in soft science has not developed well in China.

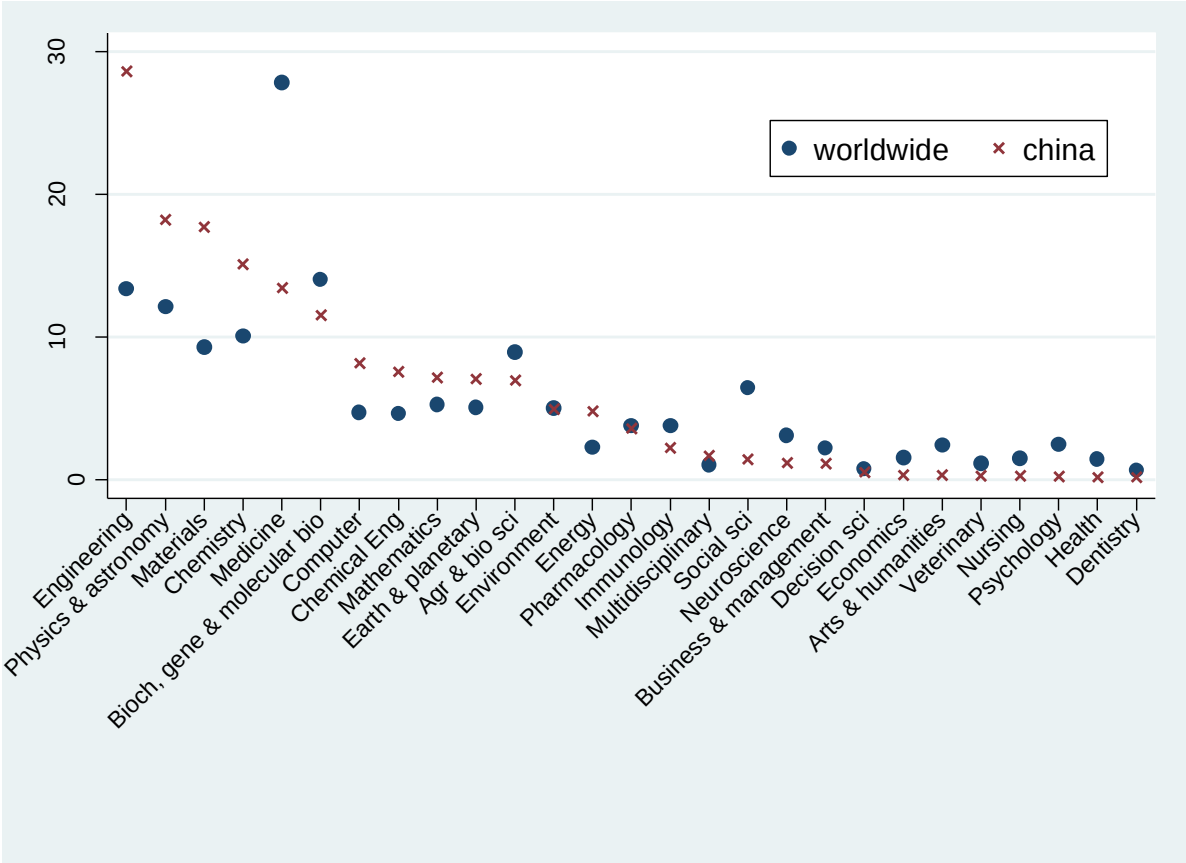

Figure 12. Share of academic disciplines, China vs. Worldwide

Source: Scopus - SciVerse Elsevier.

Note: This is calculated on the basis of total publications between 2000 and 2013

Fastest growing fields

China's fastest growing fields - which can indicate its future development direction - were also found to be different from the global trend (Table 3). The emerging field immunology and microbiology has been booming with a growth of 28% per year, although its share of China's total publications in 2011 was rather low. In contrast, strong fields with larger proportions in the total publications grew at a relatively slower speed. For instance, Chemistry, Materials science, Physics and Astronomy, and Engineering increased by less than 20% per year. An exception is Pharmacology, Toxicology and Pharmaceutics which had a low share in the national total academic output and also grew slower than 20% per year.

However, regardless of the field taken into consideration, the growth rate of Chinese publications was always a lot higher than that of the aggregated global total. Table 3 shows that annual growth rates of Chinese publications in all of the selected twelve fields were 10% higher than those of the worldwide total.

Table 3. Comparison of growth rate by field (China vs. worldwide)

WORLDWIDE			CHINA			GROWTH RATE DIFFERENCE
12 fields	Growth rate 2000-11	ratio to the total (2011)	12 fields	Growth rate 2000-11	ratio to the total (2011)	(China vs worldwide)
Computer Science	10.1%	0.06	Immunology and Microbiology	28.0%	0.03	24.8%
Engineering	7.5%	0.15	Computer Science	27.5%	0.10	17.4%
Materials Science	7.2%	0.11	Environmental Science	25.7%	0.06	18.5%
Environmental Science	7.1%	0.05	Agricultural and Biological Sciences	25.3%	0.08	18.5%
Agricultural and Biological Sciences	6.8%	0.10	Medicine	24.7%	0.15	18.3%
Chemistry	6.7%	0.11	Biochemistry, Genetics and Molecular Biology	23.9%	0.13	18.5%
Medicine	6.4%	0.30	Energy	21.4%	0.05	15.3%
Energy	6.1%	0.03	Engineering	20.8%	0.30	13.3%
Pharmacology, Toxicology and Pharmaceutics	5.5%	0.04	Pharmacology, Toxicology and Pharmaceutics	19.1%	0.04	13.6%
Biochemistry, Genetics and Molecular Biology	5.4%	0.14	Physics and Astronomy	18.3%	0.20	13.4%
Physics and Astronomy	4.9%	0.13	Materials Science	17.9%	0.20	10.7%
Immunology and Microbiology	3.3%	0.04	Chemistry	17.7%	0.17	10.9%

Source: Scopus - SciVerse Elsevier. Note: Growth rate is calculated by the exponential growth.

To shed light on the strengths and weaknesses of the research fields in China, Figure 13 shows China's development trends with global benchmarks. It provides the share of Chinese publications in the total global publications.

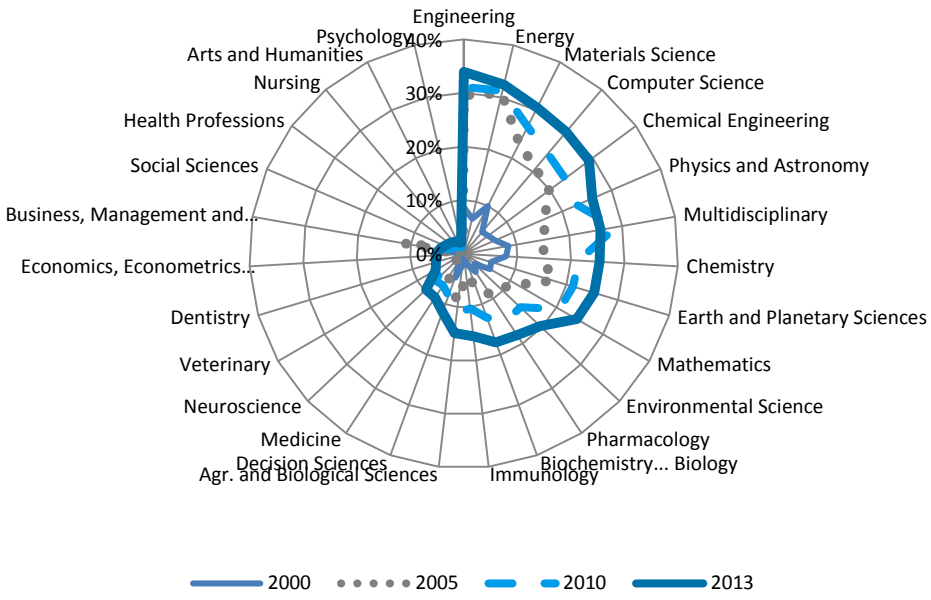

Figure 13. Subject fields of Chinese publications as percentage of worldwide total

Note: Fields are ranked by their percentage values in 2013.

The percentage share of Chinese publications in the total worldwide output by field reveals the strengths and weaknesses of research capabilities in China. The country shows a clear competitive advantage in natural sciences, such as Engineering, Materials science, and Computer science. On the contrary, research in social sciences, for instance Psychology and Arts and Humanities, has not progressed to the same level.

As shown in Figure 13, China's top five strongest research fields were Engineering, Energy, Materials science, Computer science and Chemical engineering, while the five weakest fields were Psychology, Arts and Humanities, Nursing, Health professions and Social science. For 2013 the publications in Engineering, Energy, Materials science, Computer science and Chemical engineering, accounted for respectively 34%, 32%, 30%, 30% and 29% of the global total. However, the global shares of China's

Psychology, Arts and Humanities, Nursing, Health professions and Social science fields were only between 2 % and 4 %.

Collaboration with the EU[11]

China's rising role and global influence in academic research is not only reflected by its research output in terms of numbers of publications, but also by its global collaboration and integration performance, which has an even more direct influence on other nations. In this section, an analysis of the performance of research efforts between China and the EU in 6 selected subject fields is provided. To shed light on the collaboration prospect in quantity and quality terms, the analysis covered not only the total collaborated output but also examined joint papers in high impact journals.

The selected subject fields were:

- Chemistry;
- Computer science;
- Environmental science;
- Medicine;
- Pharmacology, Toxicology and Pharmaceutics;
- Physics and Astronomy.

First, the number of co-authored papers between China and the EU were identified. In order to have a full comparative view, research efforts between China and all foreign countries and the US were also taken into consideration. Secondly, the percentage shares of these co-authored papers in the total Chinese publications were calculated.

- % share of the publications with foreign co-authors;
- % share of the publications with EU co-authors;
- % share of the publications with American co-authors.

Thirdly, the publication quality of these co-authored papers between China and foreign countries (including the EU and the US) was assessed. By subject field, the joint research efforts published in the

11 EU refers to the EU15 up to 2003, the EU25 from 2004, and the EU27 from 2007. EU28 data was not available at the time of writing.

top 2% of the high-impact journals were examined. The selection of top journals was based on the SJR (SCImago Journal Rank) in each category. Table 4 presents the numbers of journals by field[12].

Table 4. Numbers of total journals by field

Fields	Number of Total journals	Top 2%
Chemistry	680	14
Computer Science	1031	21
Environmental Science	879	18
Medicine	5363	30
Pharmacology, Toxicology and Pharmaceutics	526	11
Physics and Astronomy	843	17

Source: Scopus and SCImago Journal Rank

As shown in Figure 14 (a-f), joint research efforts in Chemistry grew steadily during the whole period studied, and the percentage of joint publications with foreign countries in this field climbed from 13% in 2005 to 16% in 2011.

However, in Computer science, Environmental science, Medicine, and Physics and Astronomy, the collaboration percentage decreased greatly in 2005. This reduction was mainly caused by the publication boom of Chinese researchers in that period. Namely, the numerator (collaborated papers with foreign researchers) grew slower than the denominator (total publications). Afterwards, the collaboration ratio increased again in Computer science, Environmental science, Medicine, but stagnated in Physics and Astronomy (staying at 16% between 2005 and 2011).

In Chemistry, and Physics and Astronomy, China collaborated almost equally with the EU and the US. In Medicine and Pharmacology, Toxicology and Pharmaceutics, China collaborated more with the US than the EU.

12 The field of Medicine is an exception. Due to its large number of total journals in this subject field, only top 30 journals were considered in the analysis.

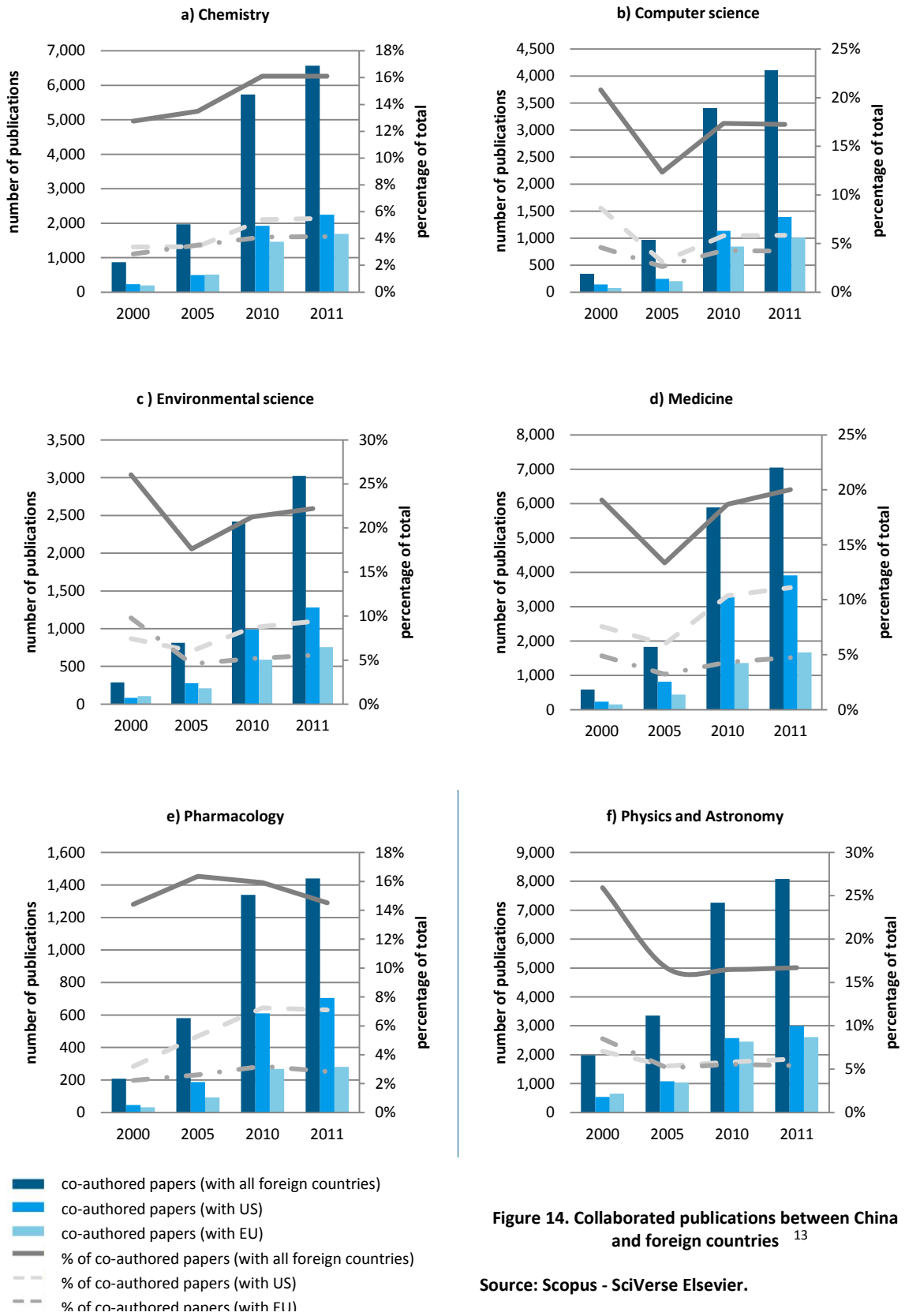

Figure 14. Collaborated publications between China and foreign countries [13]

Source: Scopus - SciVerse Elsevier.

[13] EU refers to the EU15 up to 2003, the EU25 from 2004, and the EU27 from 2007. EU28 data was not available at the time of writing.

Publication quality

Comparison of high impact publications by collaboration group shows that co-authored papers between Chinese and US scientists have had a higher impact than the average of collaborative work between China and all foreign countries (Figure 15 a-f). In four out of the six selected fields, the percentage of high impact publications between China and US reached its highest level in 2005: Chemistry (10.7%), Computer science (8.2%), Environment science (14.7%) and Medicine (6.5%). Physics and Astronomy was the only field in which the EU[14] outperformed the US in terms of the publication shares in high impact journals.

The field in which collaborative efforts had the highest impact was Environmental science, with 7.7-9.7% of the total collaborative papers appearing in relevant journals between 2000 and 2011. High-impact collaboration in Pharmacology and Physics and Astronomy emerged only after 2005. Though rising over years, the shares of collaborated publications were still rather low until 2011.

14 EU refers to the EU15 up to 2003, the EU25 from 2004, and the EU27 from 2007. EU28 data was not available at the time of writing.

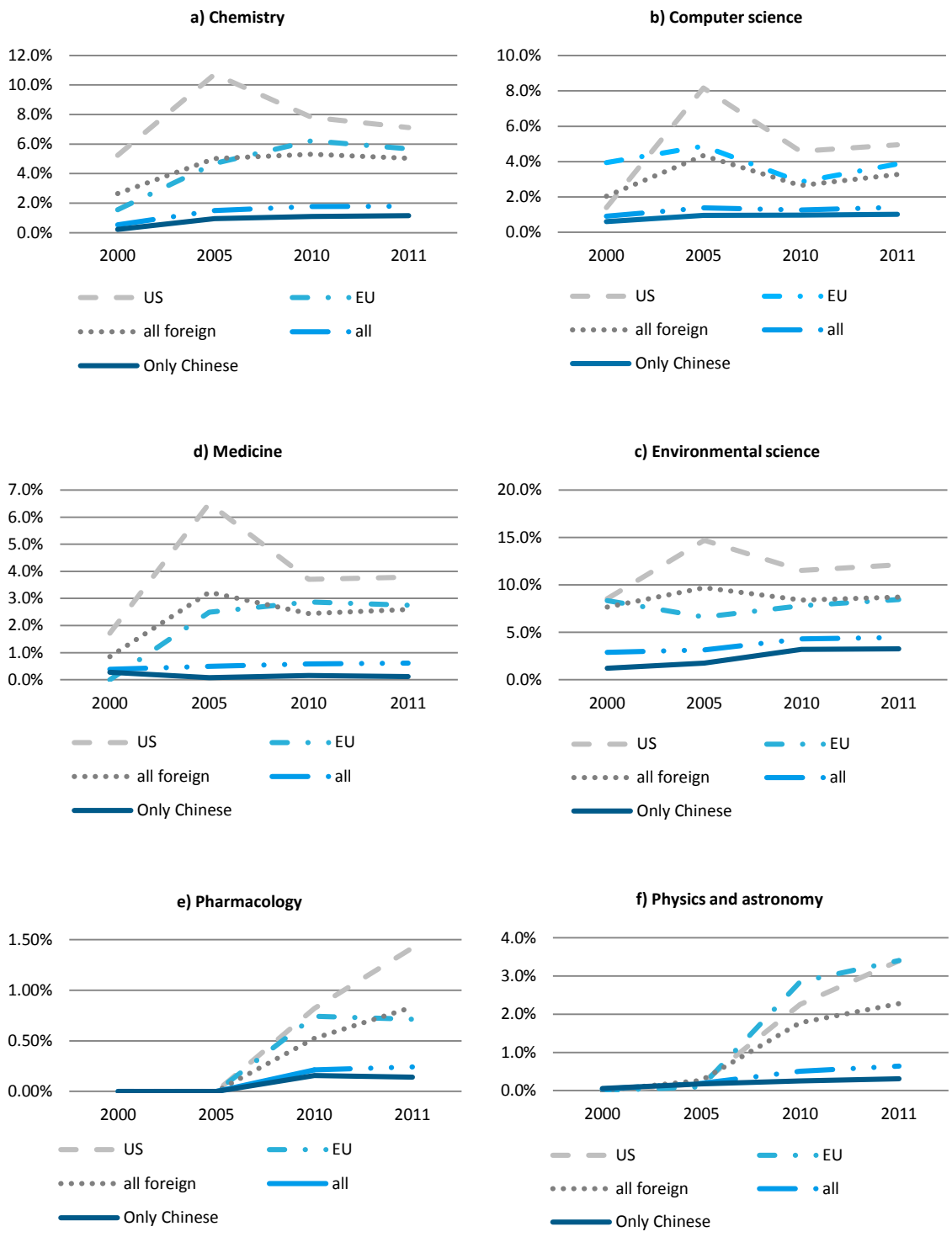

Figure 15. Share (%) of publications in high impact journals[15]

Source: Scopus - SciVerse Elsevier.

15 EU refers to the EU25 from 2004, and the EU27 from 2007. EU28 data was not available at the time of writing.

To have a better view on the collaborative research with China, the EU[16] was compared with the US in Figures 16 and 17. The number of joint publications between the EU and China was divided by the number of joint publications between the US and China. Thus, a value greater than 1 indicates that China had more collaborative research with the EU than the US, while a value less than 1 means that China collaborated more with the US than the EU.

Considering the fact that the volume of collaborative research between China and foreign countries was rather low in 2000, two benchmark years - 2005 and 2011 - were selected for this comparison.

As seen in Figure 16, in 2005, in terms of the total collaborative research with China, the EU was at a slightly higher level than the US in Chemistry (EU/US=1.04), and at a similar level in the rest of the fields. In Computer science and Environmental science, this value was around 0.8. The values in all fields dropped in 2011 (Figure 17), indicating that the US performed more collaborative research with China while in 2011 the EU decreased its share in the selected fields.

Regarding "high quality collaboration", defined for the purposes of this analysis as publications in high impact journals, the EU/US ratio increased in almost all fields from 2005 to 2011: Chemistry from 0.45 to 0.60, Computer science from 0.50 to 0.57, Environmental science from 0.34 to 0.41, Medicine from 0.21 to 0.31 and Physics and Astronomy from 0.50 to 0.87. The only field in which the value decreased is Pharmacology, Toxicology and Pharmaceutics. However, this needs to be treated with caution, given that the total publication numbers in this field were rather low and thus small changes in the numbers of co-publications can be exaggerated.

16 EU refers to the EU25 from 2004, and the EU27 from 2007. EU28 data was not available at the time of writing.

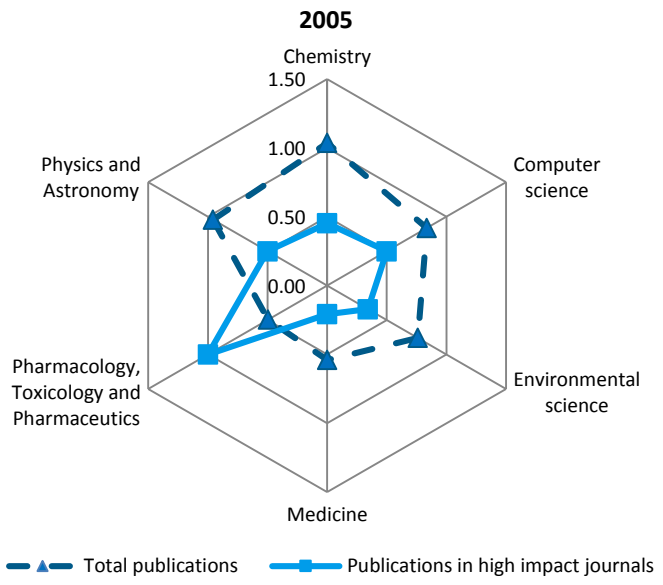

Figure 16. Joint publications with Chinese institutes in 2005 (EU[17]/US)

Source: Scopus - SciVerse Elsevier.

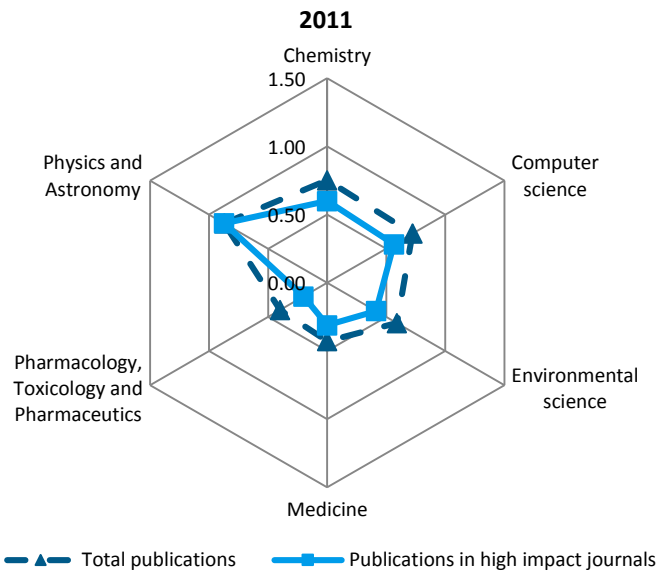

Figure 17. Joint publications with Chinese institutes in 2011 (EU[18]/US)

Source: Scopus - SciVerse Elsevier.

[17] EU refers to the EU25.

[18] EU refers to the EU27.

3. Mapping of China's research and innovation capabilities in selected technologies

Sociedade Portuguesa de Inovação
UNITED NATIONS UNIVERSITY
UNU-MERIT
AUSTRIAN INSTITUTE OF TECHNOLOGY
TOMORROW TODAY

3. Mapping of China's research and innovation capabilities in selected technologies

WP2 of this project developed a comprehensive overview of China's research and innovation capabilities across selected technologies and industrial sectors. This chapter provides an in-depth analysis of China's strengths and weaknesses in terms of patent specialisation following the International Patent Classification (IPC), and China's development in various industries in terms of R&D expenditure. The analysis compares R&D activities of Chinese firms in eight sectors and in specific cross-cutting technologies to those of the EU-27.

The Sectoral Approach

Eight industrial sectors were selected for the empirical analysis. The sectors were defined at the NACE two-digit level:

- C20 - Chemical Products
- C21 – Pharmaceuticals
- C25 – Fabricated metal products
- C26 – Computers, electronic, optical products
- C27 – Electrical equipment
- C28 - Machinery and equipment
- C29 - Motor vehicles
- C30 - Other transport equipment (with a special focus on C30.1, ships and boats and C30.3, the aerospace industry)

It was initially intended also to include one service sector, namely the sector J62 - Computer programming, consultancy and related activities. However, due to severe data limitations, this sector had to be eliminated.

Definition of cross-cutting technologies

In addition to the sectorial approach introduced above, three major cross-cutting technologies were analysed. These technologies do not follow the traditional industry classification, but are of special importance, also in light of the EU policy towards grand challenges:

- Biotechnology;
- Environmental Technologies (with a special focus on wind and solar photovoltaic energy);
- Nanotechnology.

While environmental technologies and biotechnology are clearly related to more than one of the grand challenges (e.g. Cities/Transport, Climate Change, Water, Health), nanotechnology can be considered as an important cross-cutting technology with potential positive impact in light of most of the challenges.

As seen in Figure 18, the sectors included and the cross-cutting technologies clearly overlap (e.g. Pharmaceuticals and Biotechnology). However, it is evident that the cross-cutting technologies are not limited to the sectors in the detailed analysis provided.

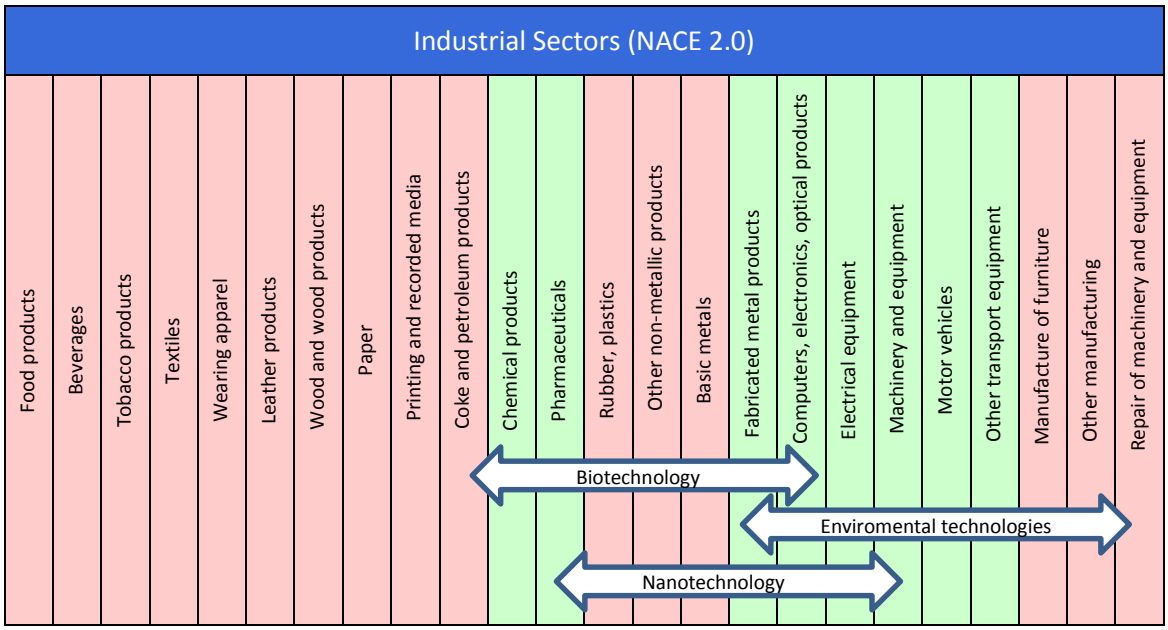

Figure 18. Selected manufacturing industries and cross-cutting technologies (green)

Data

The analysis mainly employs two analytical indicators, patent counts and R&D expenditures, derived from different data sources. The main data sources used were:

- OECD, REGPAT database, January 2014;
- China Statistical Yearbook;
- Eurostat, various databases;
- OECD, STAN database;
- World Input-Output Database (WIOD).

Data from the OECD REGPAT database was retrieved to calculate all patent-related indicators used. This concerns mainly the global portfolio of PCT patenting over the years 1990-2011, disaggregated by countries or groups of countries and selected technologies matched to the industrial sectors and cross-cutting technologies introduced above[19]. Because of the low costs involved in PCT patenting and policies to stimulate PCT patenting in China, which may lead to a large number of patents with comparable low economic value (Dang and Motohashi 2013), the use of proxies of patent value, e.g. highly cited patents and/or triadic patents was also considered. However, triadic patent data is only fully available up to the year 2006 and would not be able to capture current developments in patent activity. When using citation data the large citation lags of up to 15 years has to be considered, the time period under consideration would only be rudimentarily observable. In a similar way also other patent value measures are just observable a rather long time period of up to 10-15 years after patents have been granted, additionally different measurement approaches are currently used that are not yet fully developed.

Information from the China Statistical Yearbook has been used to gather data on Chinese R&D expenditures over the years 2000-2010 across the selected manufacturing sectors, while data from Eurostat provided the same information for the EU[20], and data from the OECD Stan database for the US and Japan. This was necessary for comparison purposes in the STI development of China as

19 Matching procedures described in inception report:
In the case of the industrial sectors considered some data, in particular on R&D expenditures, is already available in the structure needed. However, patent data as a major input in this work package is classified along technologies and not industrial sectors. Therefore, the patent data will be transformed into industrial sectors using the concordance tables provided by Schmoch et al. In case of two of the cross cutting technologies, the OECD has identified relevant IPC and European Classification System (ECLA) codes to match patents with environmental Technologies (ENV-Tech Indicators) and biotechnology . Patents relevant for the third cross-cutting technology considered, nano-technologies, can be identified via the ECLA code.
20 EU refers to the EU15 up to 2003, the EU25 from 2004, and the EU27 from 2007. EU28 data was not available at the time of writing.

compared to the EU, but also to the US and Japan. For data on the industrial structure (sectoral value added and production) and exports, the World Input-Output Database (WIOD) was used[21].

3.1. China's industrial structure in comparison

Differences in the industrial structure of China and the EU[22]

Before the data on R&D expenditures and patent applications were examined in detail, China's industrial structure was studied and compared with that of the EU. The industrial structure can be measured by using data from 2009 on total production (Figure 19) and value added (Figure 20). A considerable specialization of China in 'Electrical and optical equipment' was revealed. 'Electrical and optical equipment' includes two sectors – 'Computers, electronic, optical products' (C26) and 'Electrical equipment' (C27). Additionally, a high importance of the sector 'Metal and metal products' (including NACE 2.0 section C25 'Fabricated metal products'), some low-tech-manufacturing sectors (most notably 'Textiles, apparel, and leather'), 'Agriculture' and 'Mining' was found.

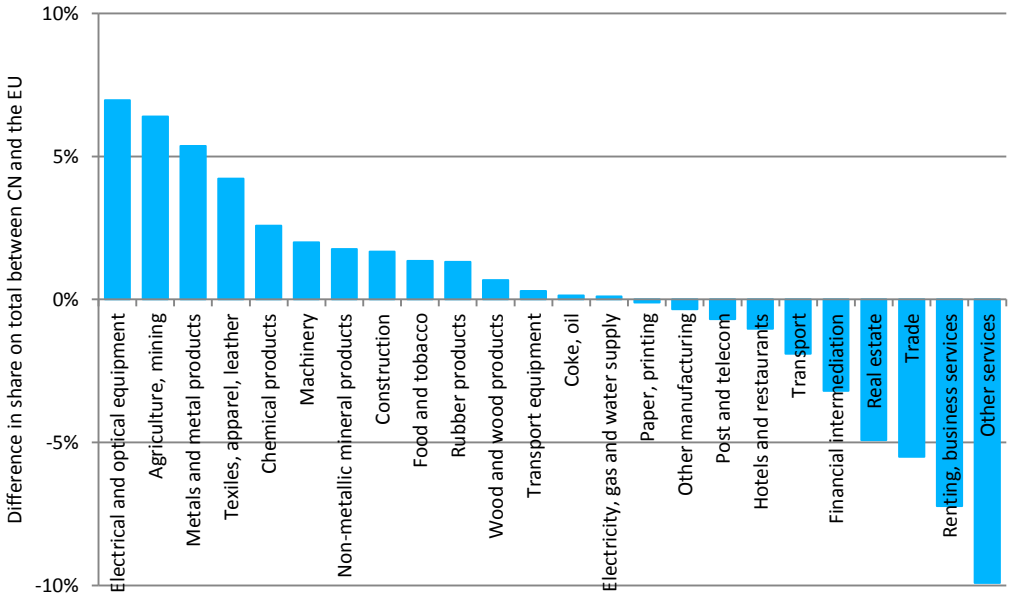

Figure 19. Difference in sector shares on total production between CN and the EU[23], 2009

Source: WIOD, own calculations

Note: NACE Rev. 1.1

21The data used are taken from the World Input-Output Database (WIOD), (see www.wiod.org). It was compiled on the basis of national accounts, national supply and use tables and detailed trade data on goods and services, combining information for 59 products and 35 industries. More detailed information is provided by Timmer et al. (2012) and Dietzenbacher et al. (2013).

22 EU refers to EU27.

23 EU refers to EU 27.

With very few exceptions, the shares of all manufacturing sectors in total production (and to a lesser extent also in value added) were higher in China than the EU. In contrast, all the services sectors played a much smaller role in China's economic structure. Therefore not only the importance of certain manufacturing sectors was found to differ between China and the EU, but also the weight of the manufacturing sector as a whole in China appeared be to much larger than in the EU.

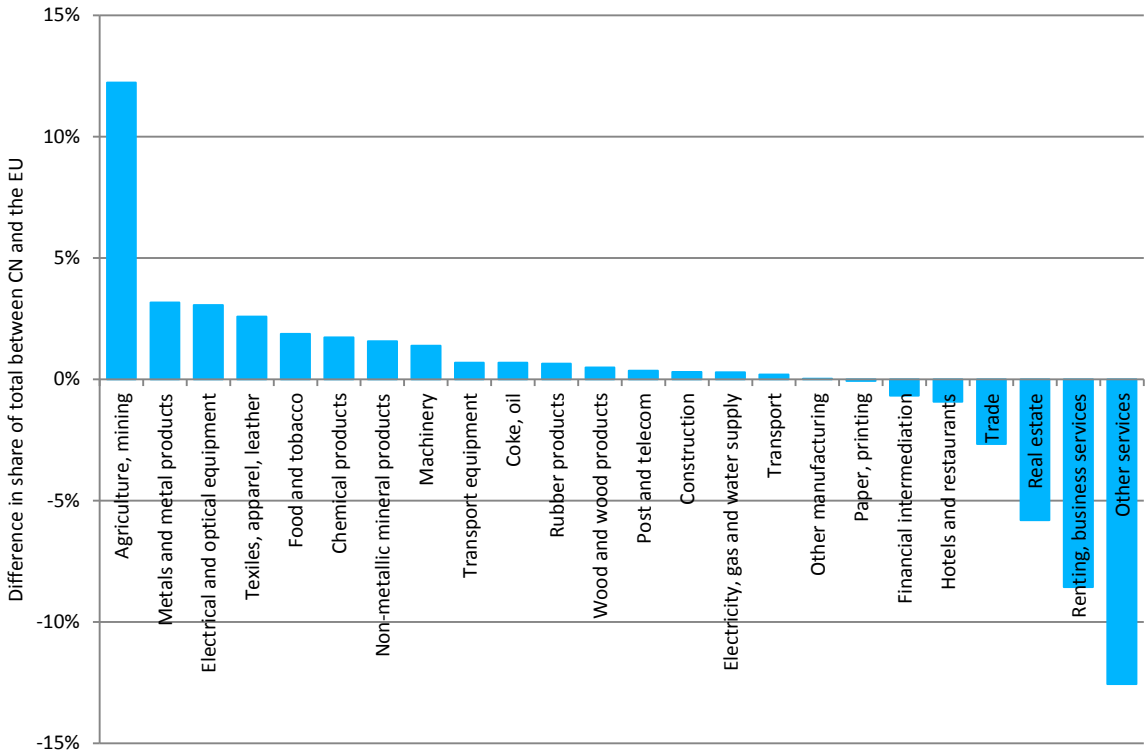

Figure 20. Difference in sector shares on total value added between CN and the EU[24], 2009

Source: WIOD, own calculations

Note: NACE Rev. 1.1

The absolute numbers reveal that in some sectors both the relative importance of the sector was higher in China compared to the EU and that the absolute value of the production was above the level of the EU. These sectors included a number of low-tech manufacturing sectors, among which was 'Textiles, apparel and leather' for which China's production in 2009 was three times higher than that of the EU. However, China's 'Electrical and optical equipment' production was also higher than that of the EU by a factor of two. In contrast, in all other high- and medium-high-tech manufacturing sectors

[24] EU refers to EU27.

the total EU production was above the value for China. Total production of the 'Transport equipment' sector was two times higher in the EU compared to that in China in 2009.

Export specialization of China compared to the EU[25]

Using a similar approach the differences between the export specialization of China and the EU were examined in the year 2009 (Figure 21). In only two sectors – 'Electrical and optical equipment' and 'Textiles, apparel, leather' – did the identified high specialization in production also translate into a high export specialization. The other manufacturing sectors with high shares of total production seemed to be more oriented towards the Chinese domestic market. One example of a sector with such a pattern (a high share in production, but a low share in total exports) was 'Metal and metal products'. The two sectors with the highest identified share in total Chinese exports ('Electrical and optical equipment' and 'Textiles, apparel, leather') together accounted for more than half of all Chinese exports in 2009. In contrast, EU exports were more equally distributed across economic sectors. In the case of the EU, the sector with the highest share in total exports – 'Transport equipment' – only accounted for less than 12% of total exports.

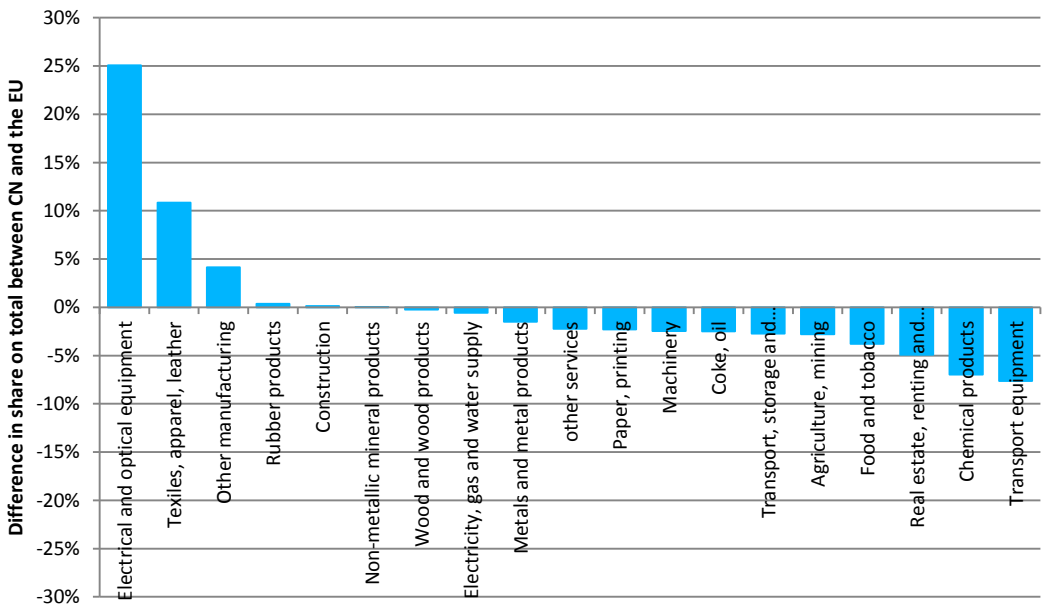

Figure 21. Difference in sector shares on total exports between CN and the EU[26], 2009

Source: WIOD, own calculations

Note: NACE Rev. 1.1

25 EU refers to EU27.
26 EU refers to EU27.

Analysing total exports for China and the EU[27], Figure 22 shows that EU exports were still about four times the value of Chinese exports in absolute terms in the most recent year where data is available (2009).

Only in the sector 'Electrical and optical equipment' was the value of Chinese exports close (75%) to the EU value. However, the absolute figures also reveal the much faster growth of Chinese exports compared to those of the EU. In 1995, Chinese 'Electrical and optical equipment' exports were only 10% of the EU value. While Chinese exports in other sectors grew significantly over the last 14 years, the value of EU exports was between more than three ('Fabricated metal products') and 27 ('Motor vehicles') times higher than the corresponding Chinese exports in 2009. However, it should be noted that EU exports also include intra-EU Exports. If only extra-EU exports were included the gap between China and the EU in term of total exports would be significantly smaller.

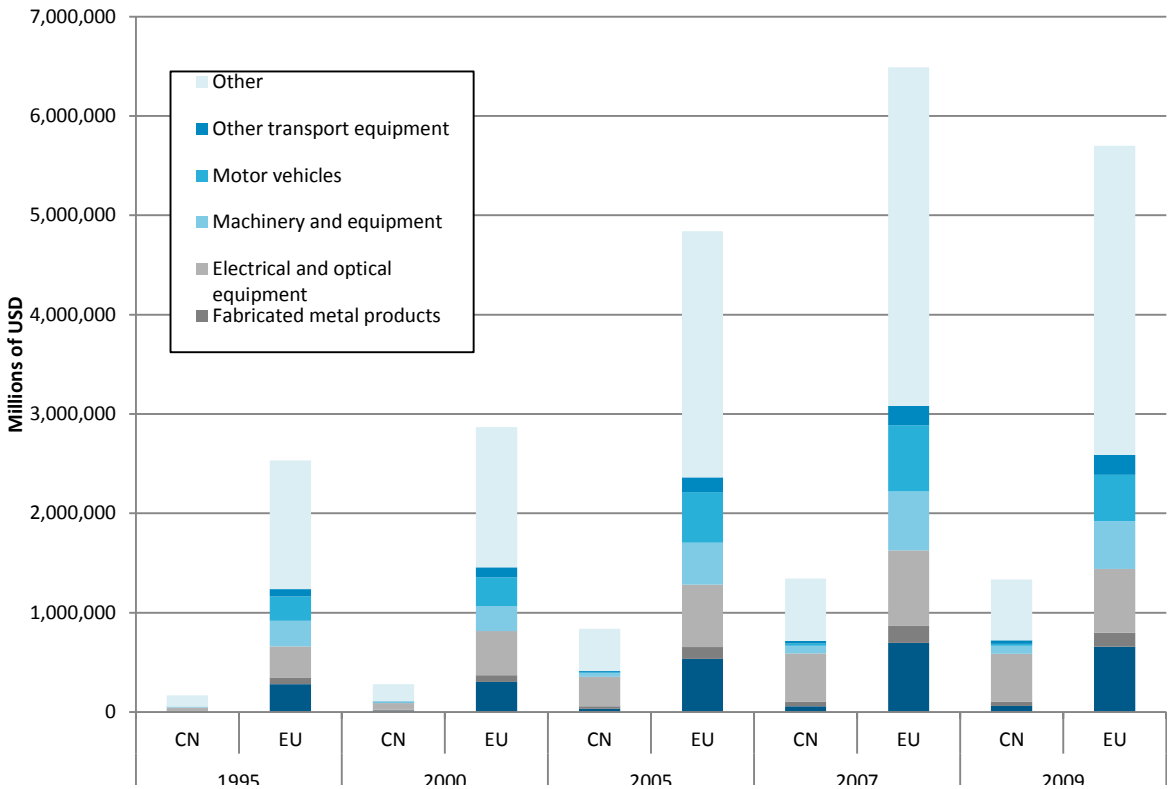

Figure 22. Total exports and exports in selected sectors of China and the EU[28], 1999, 2000, 2005, 2007 and 2009

Source: WIOD, own calculations

Note: NACE Rev. 1.1

[27] EU refers to the EU15 up to 2003, the EU25 from 2004, and the EU27 from 2007.
[28] EU refers to the EU15 up to 2003, the EU25 from 2004, and the EU27 from 2007.

3.2. China's overall research, development and innovation performance

Trends in China's industry R&D

This section is focused on the development of China´s industrial R&D expenditures, disaggregated by different sectors of economic activity in comparison to the EU[29], the US and Japan. R&D expenditures have been widely used in studies measuring the STI performance of firms, regions or countries as an indicator for the ability to generate innovations. More specifically, industry R&D expenditures have been commonly considered to be one of the main drivers of generating new products and/ or new processes that induce added value and foster productivity and growth (see, for example, Mairesse and Sassenou, 1991). The R&D expenditures are generally measured in Euro at current prices.

In the empirical analysis, only sectors in the China Statistical Yearbook were considered to measure the development of industrial R&D expenditures along with the selected sectors of interest (see Section 3.3). These sectors were matched with the NACE rev. 2 classification for sectors of economic activity in order to compare Chinese R&D expenditures with the those of the EU, the US and Japan. Correspondingly, data on Chinese R&D expenditures were sourced from the China Statistical Yearbook, while for the EU, the US and Japan, data was gathered from Eurostat, the OECD and national statistical offices.

Development of total R&D expenditures

Prior to analysis of the development of R&D expenditures from a sectorial perspective, it is appropriate to discuss the general development of R&D expenditures in China as compared to other countries. This can shed some light on the overall importance of R&D in the Chinese economy, and the role of China in the world in terms of R&D. Figure 23 illustrates country shares of total R&D expenditures worldwide (including firms, universities and public actors) for the years 2002, 2007 and 2009, while Figure 24 shows the development of total R&D expenditures as a percentage of gross domestic product for the time period 2000-2012.

29 EU refers to the EU15 up to 2003, the EU25 from 2004, and the EU27 from 2007.

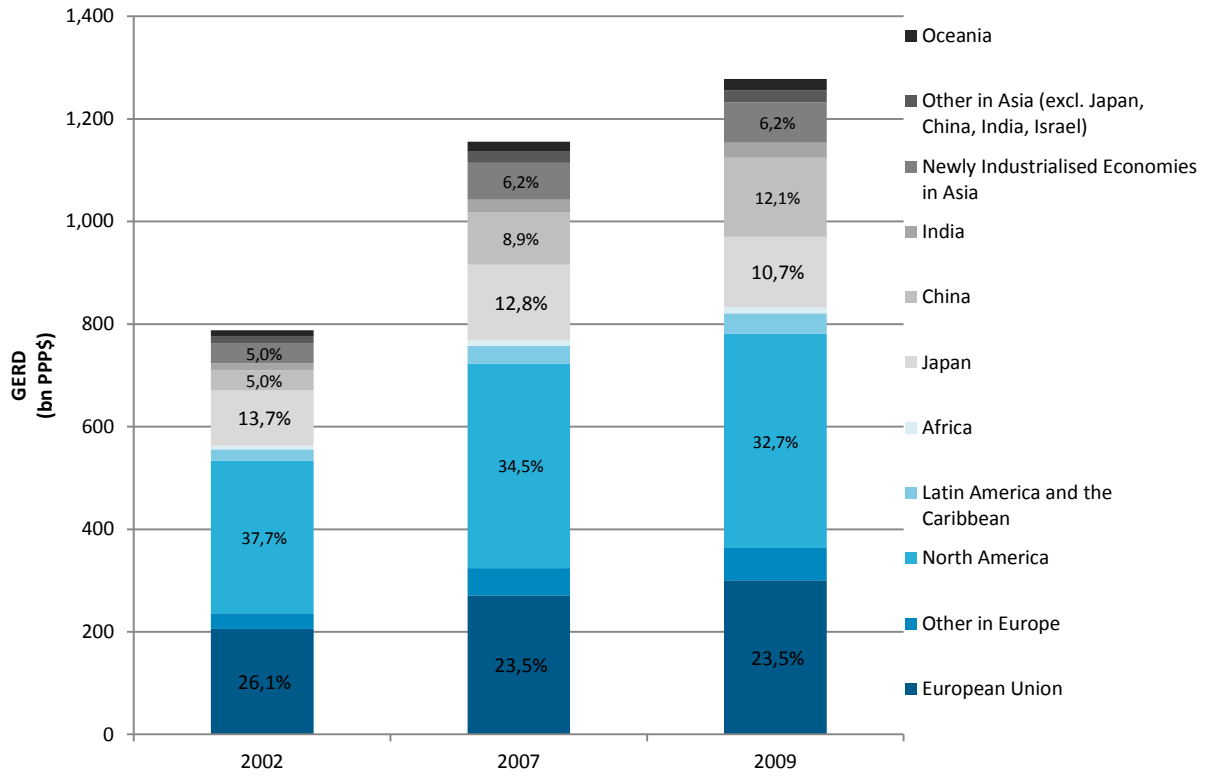

Figure 23. Global shares of total R&D expenditures (GERD), 2002, 2007 and 2009

Source: UNESCO, own calculations[30]

Two important trends can be seen. Firstly, that there was a significant overall increase in global R&D expenditures between 2002 and 2009, from roughly 800 billion USD in purchasing power parities (PPP) to 1,250 billion USD PPP. Secondly, that the distribution of global shares has also changed considerably during this period:

- North America, including the US and Canada, had the highest share of global R&D expenditures. However, North America's share has gradually decreased between 2002 and 2009 in relative terms from 37.7% to 32.7%.
- Japan's global share has decreased from 13.7% to 10.7% between 2002 and 2009. Between 2007 and 2009, Japan's R&D expenditures slightly decreased also in absolute values, related to the global economic crisis in this time period.

30 European Union refers to the EU15 up to 2003, the EU25 from 2004, and the EU27 from 2007. EU28 data were not available at the time of writing.

- For the EU[31], R&D expenditures in absolute values have increased, roughly with the same magnitude as the US. However, the share of the EU in global R&D has stagnated between 2007 and 2009.
- In contrast to the other countries under consideration, China has increased its total R&D expenditures significantly, both in terms of absolute values as well as in terms of its global share in total R&D expenditures. The global share has more than doubled between 2002 and 2009, from 5% to 12.1%. In 2009, China's global share on total R&D expenditures (12.1%) exceeded the global share of Japan (10.7%). During the financial crisis of 2008/09, a period characterized by decreasing R&D expenditure in some countries, China's total R&D expenditures have continued to increase. Given the trend to be observed from Figure 24, it can be assumed that China will maintain the third position behind North America and the EU27 in the mid-term, and further close the gap to the EU27 in the mid- to long-term.

Figure 23 also clearly indicates that the rise of China in terms of absolute R&D expenditures was not accompanied by a decline of the EU, North America and Japan. For the whole period, R&D expenditures in all three economic regions increased; the share of the EU only decreased relative to total global R&D expenditure.

These results convincingly illustrate the rapid growth of R&D expenditures in China and the efforts of the country in catching-up. It points, on the one hand, to a deeper shift in the structure of the Chinese economy with a growing share of knowledge intensive industries, in particular telecommunications and electronics. On the other hand, it also reflects considerable efforts by the Chinese government to accelerate the transformation of the Chinese economy to a more technology-driven, knowledge based economy (see, for example, Scherngell et al. 2014).

China's catching up becomes even more impressive if the observation period is enlarged and total R&D expenditures as a percentage of GDP are compared to illustrate the R&D intensity of countries relative to their economic size. Figure 24 outlines this indicator for China, Japan, the US and the EU[32] for the period 2000-2012. In the last decade China nearly doubled its R&D intensity and overtook the EU in 2012.

31 EU refers to the EU15 up to 2003, the EU25 from 2004, and the EU27 from 2007. EU28 data were not available at the time of writing.
32 EU refers to the EU15 up to 2003, the EU25 from 2004, and the EU27 from 2007. EU28 data were not available at the time of writing.

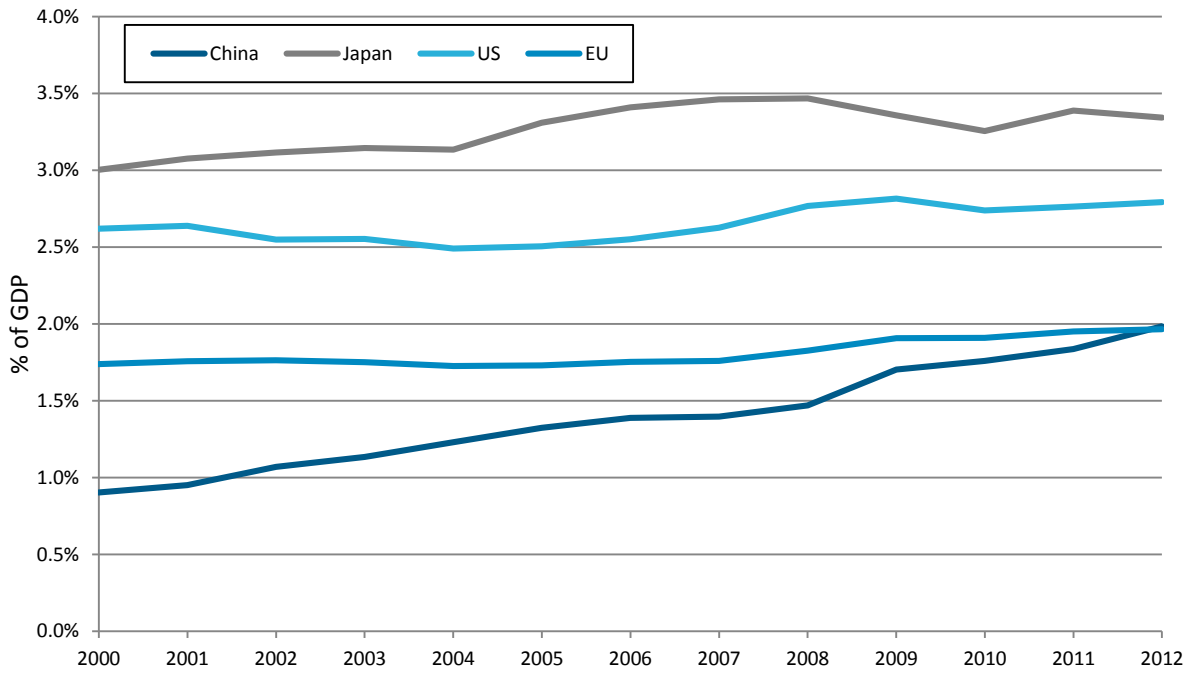

Figure 24. Total R&D expenditures (2000-2012) as a percentage of GDP

Source: OECD, own calculations[33]

The development points to a constant and considerable growth in private R&D expenditures of firms located in China between 2000 and 2012. This trend is likely to continue in the near future as there is no implicit or explicit evidence of factors that may reduce this growth pattern in the mid-term. While in 2000, private actors located in China spent around 12 billion Euros on R&D, this value has increased to 78 billion Euros in 2010, i.e. the magnitude of private R&D expenditures increased by a factor of 6.5 in this period. This tremendous growth cannot only be explained by a changing innovation behaviour of some selected firms; it has rather to be related to a more pervasive structural shift of the Chinese economy from low- and medium-tech industries to medium-high- and high-tech industries, such as telecommunications and electronics (see, e.g., Crescenzi et al. 2012). In related literature, a number of explanations for this development have been identified, most importantly the absorption of technological knowledge via foreign direct investment (FDIs), and massive government support for knowledge diffusion from basic to applied research and development (see, e.g., Scherngell et al. 2014). Further it is worth noting that - as also observed for total R&D expenditures - growth of private R&D

33 EU refers to the EU15 up to 2003, the EU25 from 2004, and the EU27 from 2007. EU28 data were not available at the time of writing.

expenditures has not been subject to a hiatus during the years of the global economic crisis. In contrast, growth of private R&D expenditures in this period was even slightly higher than before.

An interesting question that arises in this context concerns the role of foreign-owned firms in the overall development of R&D expenditures in China. China initially served as an assembler of more sophisticated inputs imported from abroad - often referred to as the Chinese 'workbench economy' – driven by cheap factor inputs, in particular cheap labour. Meanwhile, however, there are also signs indicating that foreign-owned firms are increasing their R&D activities in China, utilizing millions of skilled Chinese engineers and scientists, with their new competencies to develop products specifically designed for the Chinese market. However, the figures on foreign R&D activities provided by Chinese sources are ambiguous and difficult to interpret (Zahradnik and Urban 2014). It is clear that R&D activity of European and US firms in China is rising fast; however, it is still considerably lower than the levels of R&D activity of US firms in the EU, or EU firms in the US (Zahradnik 2014, p. 50).

Concerning the other countries depicted in Figure 24, it is possible to observe a decline in private R&D expenditures for the US in the time period 2000 and 2010. However, firms located in the US still spend by far the highest amount of on R&D in absolute numbers with a value of around 200 billion Euros in 2010. While Japan stagnated during the observed time period at a level of 100 billion Euros, the EU countries showed a rather constant growth between 2000 and 2008. But stagnation occurred for the EU after 2008 at around 150 billion Euros per year.

Trends in China's patent output

In this section attention is given to the analysis of the development of China's patent output. When mapping the research and innovation capabilities of countries, patents are without doubt one of the most often used indicators taken into consideration. Patents are – in spite of various limitations discussed in scientific literature (see, e.g., Scherngell, 2007) - the most direct indicator of the creation of new technological knowledge that is likely to be commercialized.

In this analysis the main focus was on raw patent counts, drawing on a time series for the years 1990-2011. The International Patent Classification (IPC) was used to capture China's research and innovation capabilities for the eight sectors and three cross-cutting technologies. The REGPAT database is a data collection tool to get information on global patenting, aiming to describe the development of China's patent output in comparison to other countries and groups of countries. Within REGPAT the patents that are filed under the Patent Cooperation Treaty (PCT) of the World

Intellectual Property Organization (WIPO) have been identified, as these are most appropriate for cross-country analysis to avoid home patent office bias. Patent counts were drawn from inventors listed in patent documents, i.e. the number of inventors located in a specific country is counted. In this context, the approach of fractional counting is implemented.

Development of the total patent output

Figure 25 presents the total number of PCT patent applications of China in comparison to the United States, Japan, the EU[34], and the group of all remaining countries, labelled Rest of the World (RoW). China's share may still be small compared to the US and the EU, however, it is growing fast. A shift in global patenting share across countries was seen, in particular the increasing importance of China and RoW, the latter mainly dominated by other Asian countries such as South Korea, India, Vietnam and Thailand.

From Figure 25, the following main results can be summarized:

- Since 1978 global patenting activity has increased tremendously, in particular between the early 1990s and 2005. In 1990, the number of annual PCT patents equalled about 20,000; a number that increased to about 140,000 over a time period of 15 years;
- The EU and the US showed the highest annual number of patents, followed by Japan;
- China showed a very low patenting activity before the year 2000. However, after the millennium the number of patents increased steadily, reaching a number of about 15,000 patents in 2010 (which was around two thirds of Japan's and 50% of the US' patenting activity);
- Continuing this trend, China may further increase its share in global patenting relative to the US, Japan and the EU;
- While a steep increase in patenting in the 1990s can be seen at a similar rate in both the US and EU, Japan's patenting activity increased faster after 2000 (especially after 2003), resulting in 2010 for a nearly same performance in patenting activity as the US;
- Countries of the RoW group begin to intensify patenting earlier than China, since 2008 accounting for nearly the same figures as Japan.

34 EU refers to the EU15 up to 2003, the EU25 from 2004, and the EU27 from 2007. EU28 data were not available at the time of writing.

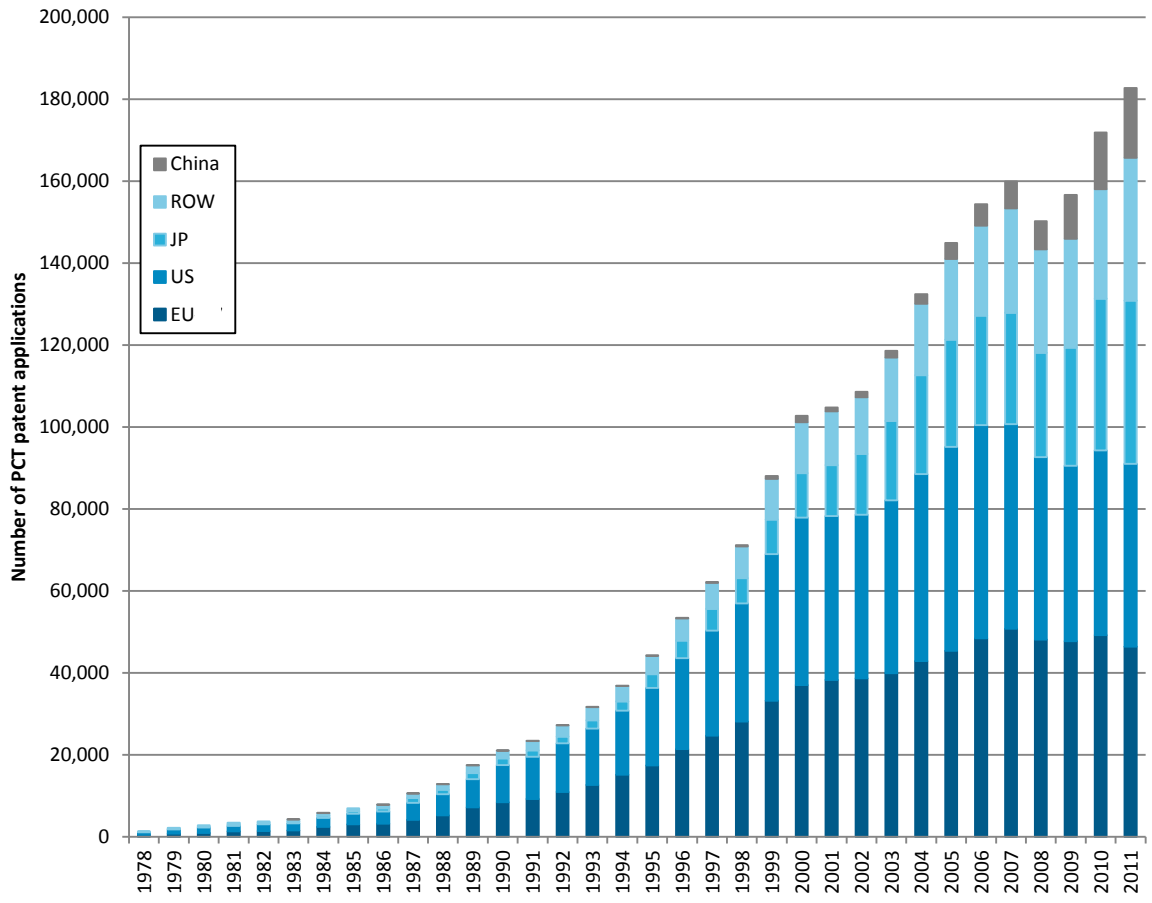

Figure 25. Number of total PCT patent applications (1990-2011)

Source: OECD, REGPAT database, January 2014, own calculations[35]

Turning to relative shares instead of absolute values (Figure 26), the shift in global patenting becomes even more evident. The share of the EU[36] and the US in global patenting gradually decreased - nearly in parallel - from around 43% in the year 1990 to less than 30% in the year 2010. Note that this decreasing trend may also be related to a general lower propensity to patent in the EU and the US. However, it is without doubt, to a substantial degree, also related to the increasing share of the other three countries and groups of countries. While China's share in global patenting started to increase noticeably after 2000, the share of RoW has steadily increased since the 1990s. Japan showed a rather low increase during the 1990s, a steep increase between 1999 and 2004, then stagnation until 2008, and a considerable increase again for 2009 and 2010.

35 EU refers to the EU15 up to 2003, the EU25 from 2004, and the EU27 from 2007. EU28 data were not available at the time of writing.
36 EU refers to the EU15 up to 2003, the EU25 from 2004, and the EU27 from 2007. EU28 data were not available at the time of writing.

The increase of China's share in world patenting was rather stable and significant, starting from nearly zero to an almost 10% share in global patents in 2011, with an average annual growth of 1% in global patenting shares. This significant growth can be explained by different developments: on the one hand by the increased opening-up, privatization and semi-privatization of China's economy during the 1990s and the settlement of foreign firms stimulating knowledge flows to the local Chinese economy; on the other hand, the Chinese government has invested tremendous resources into STI policy programmes, for instance, supporting the translation of research results from universities into the Chinese economy (see, for example, Scherngell et al. 2014, among others). These policy programmes seem to have come into effect over the past decade.

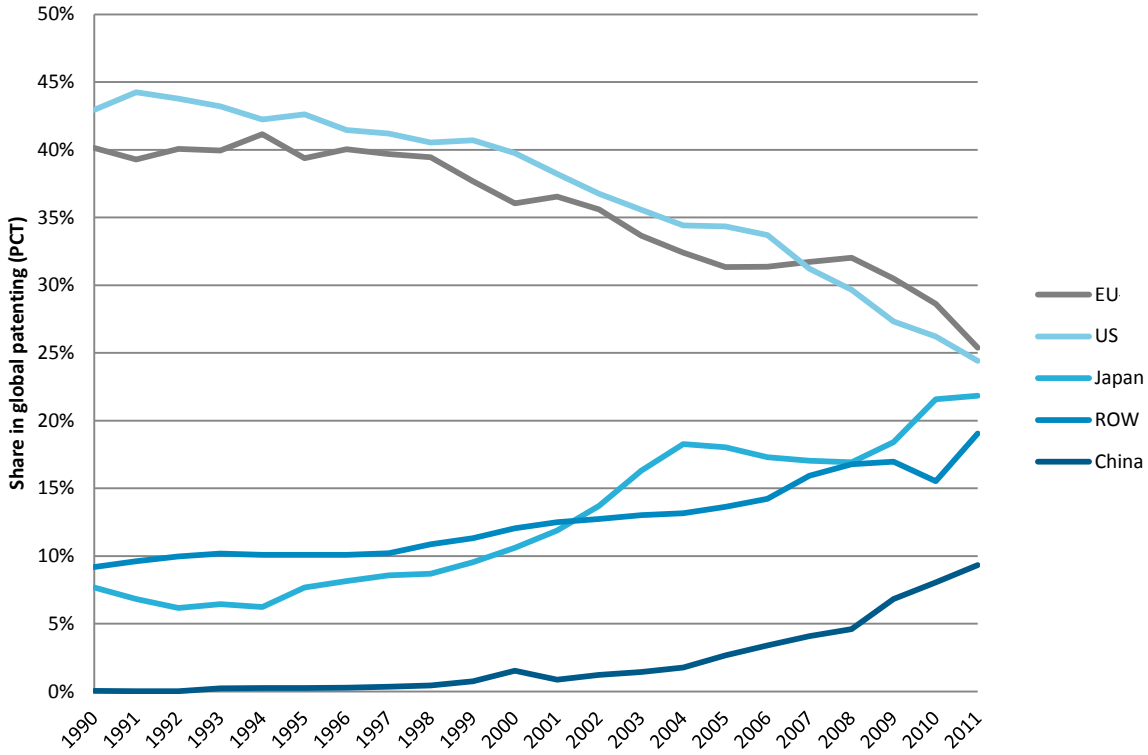

Figure 26. Share in global PCT patenting (1990-2011)

Source: OECD, REGPAT database, January 2014, own calculations[37]

However, at this point it is once more worth mentioning that cross-country comparisons using patents across all industries are problematic. Firstly, the value distribution of patents is skewed, i.e. many patents have no industrial applications, but raw patent counts assume an equal value of each patent (see, e.g., OECD, 2001). Secondly, the propensity to patent differs greatly across industrial sectors, and

37 EU refers to the EU15 up to 2003, the EU25 from 2004, and the EU27 from 2007. EU28 data were not available at the time of writing.

thus cross-country comparisons are subject to bias related to the sectoral composition of a country. Nevertheless, the main conclusion of the analysis of global patenting development holds, namely that China has increased its research and innovation capability as reflected by the considerable increase in its share of global patenting over the past decade.

3.3. Sectoral specialisation of Business R&D in China

Development of industrial R&D expenditures in selected economic sectors

The empirical analysis of total and private R&D expenditures across all sectors above provides interesting results on the general development of R&D expenditures in China. However, a sector specific view is necessary to assess sectoral trends, and to identify which sectors contribute most to the general development. Hence, in this section the analysis draws on the development of private R&D expenditures between 2000 and 2010 at the level of industrial sectors as defined in Section 3.2.

First, the relative size of private R&D expenditures in China compared to the EU was examined. Figure 27 shows Chinese R&D expenditures in 2010 in various sectors as a percentage of the R&D expenditures in corresponding sectors in the EU27.

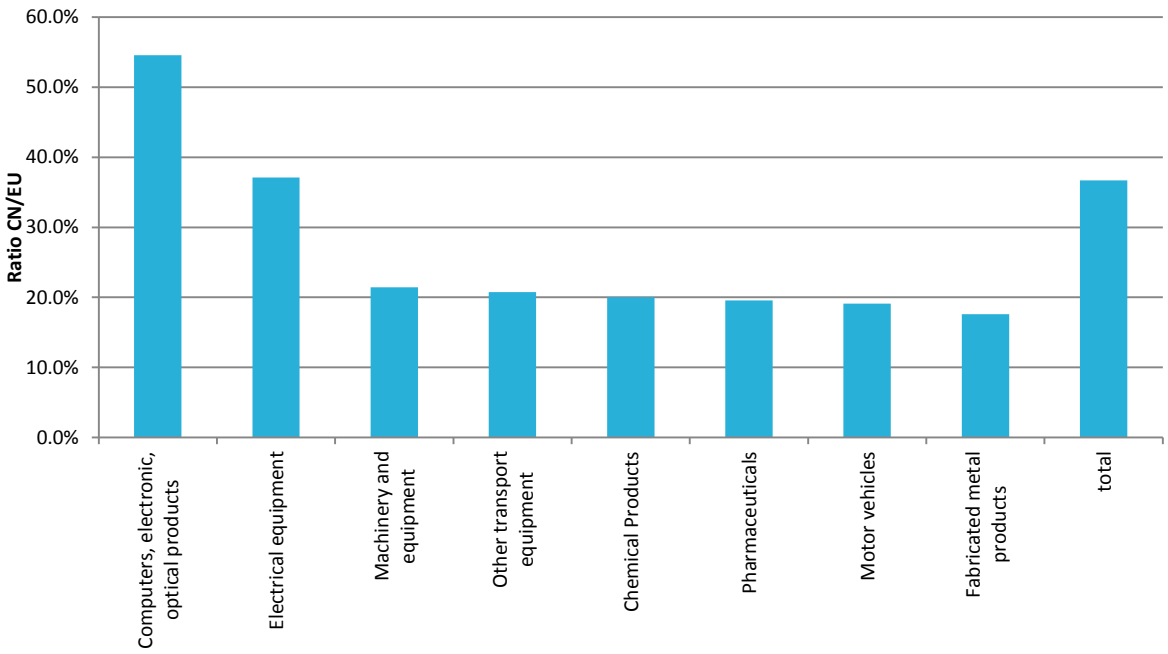

Figure 27. Private R&D expenditures in China relative to the EU27 (2010)

Source: China Statistical Yearbook, Eurostat, own calculations

'Other transport and electrical equipment'[38] is the only sector in which Chinese firms spent more than half the value on R&D than their European competitors. The gap is largest in 'Pharmaceuticals'. Altogether, Chinese firms spent around half of the amount of EU firms on R&D.

In a dynamic perspective, there is no sign of a slowing down of China's catching-up in terms of R&D expenditures (Figure 28). Catching up has even accelerated since the global financial crisis of 2008/09. This is mainly due to different reactions of EU[39] and Chinese firms to the crisis. In the EU, firms stopped expanding their R&D budget; this was not the case in China. As a consequence, catching-up has accelerated considerably since 2007.

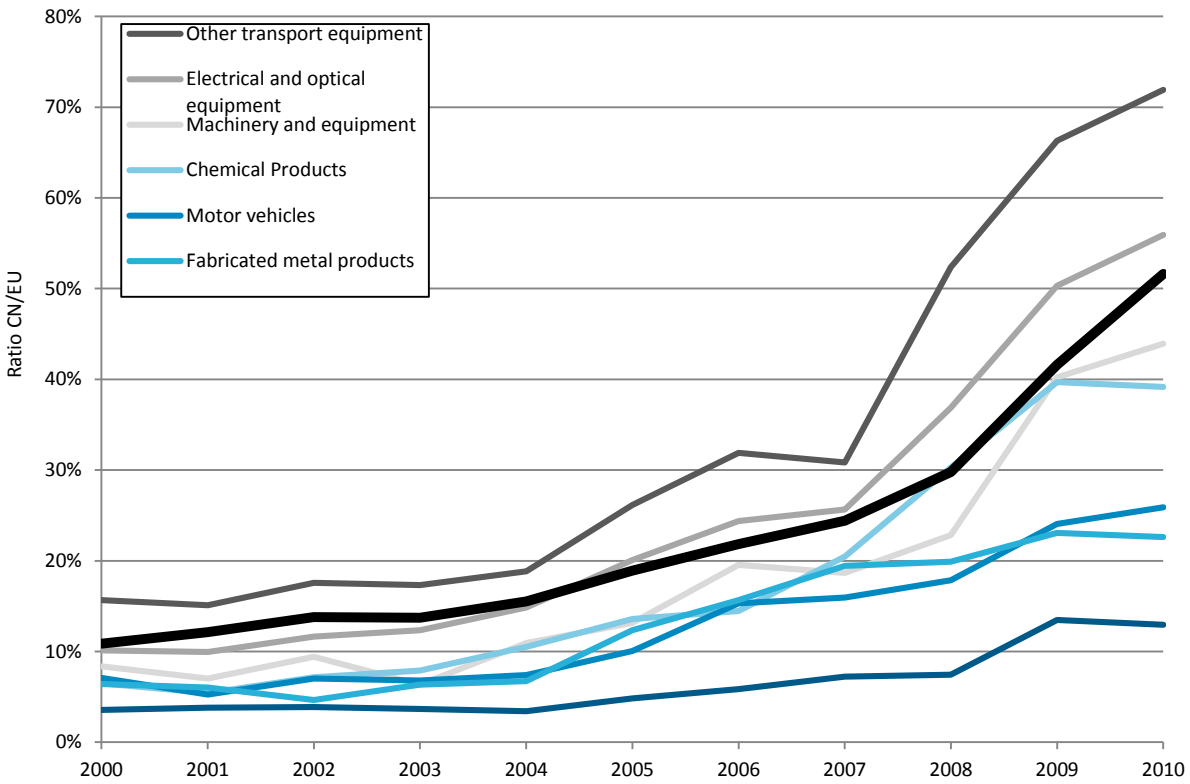

Figure 28. Development of private R&D expenditures in China relative to the EU[40] (2000-2010)

Source: China Statistical Yearbook, Eurostat, own calculations

38 Due to data constraints 'Computers, Electronics and optical products' and 'Electrical equipment' was summarized as 'Electrical and optical equipment'.
39 EU refers to the EU15 up to 2003, the EU25 from 2004, and the EU27 from 2007. EU28 data were not available at the time of writing.
40 EU refers to the EU15 up to 2003, the EU25 from 2004, and the EU27 from 2007. EU28 data were not available at the time of writing.

In the following figures, the analysis depicts the development for specific individual sectors in comparison to the EU[41], the US and Japan.

The analysis begins with 'Chemical Products' (Figure 29). The picture for China was found to be quite similar to the overall development of R&D expenditure, though the growth performance seemed to increase more after 2005. For the last period 2009-2010 - in sharp contrast to the overall development – R&D expenditure in chemicals decreased slightly. In general, other countries seem to invest much more in R&D for chemical products; however, a sharp decrease for Japan has been identified between 2000 and 2007, and for the US between 2001 and 2003. After 2003 the US - though rather volatile - more or less stayed at the same level, while Japan's R&D expenditures for chemical products considerably grew after 2007. The EU invested most in R&D in this sector in 2010, showing a small but rather constant growth between 2000 and 2010.

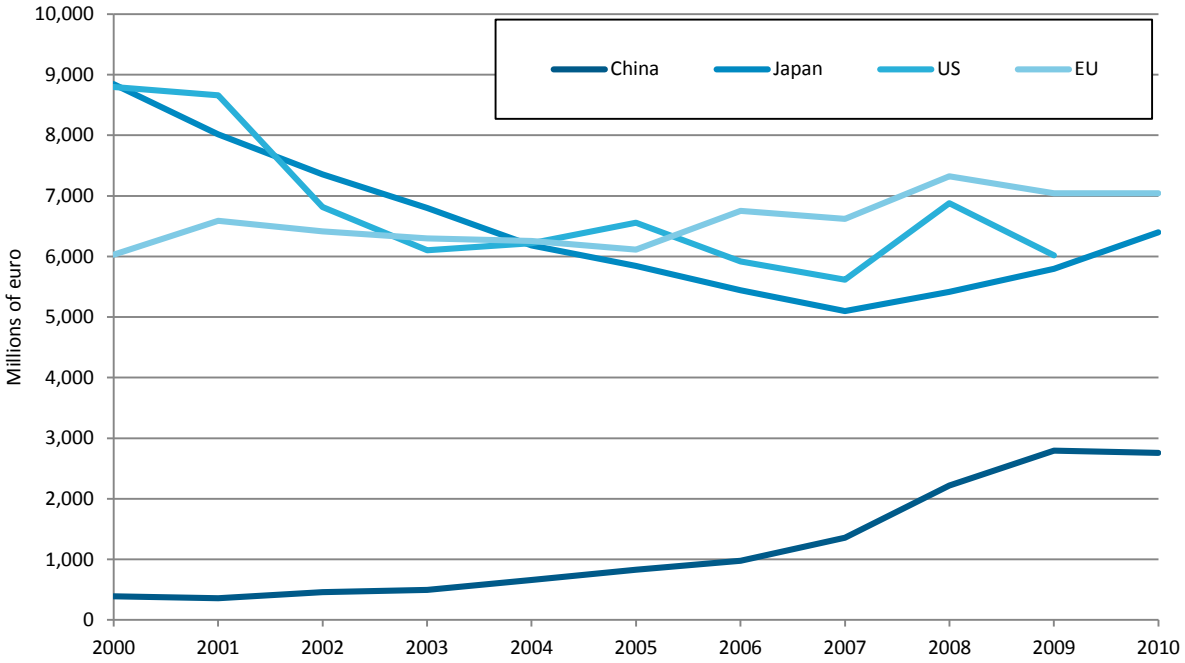

Figure 29. Private R&D expenditures for Chemical Products (2000-2010)[42]

Source: China Statistical Yearbook, Eurostat, OECD, own calculations

Figure 30 shifts attention to private R&D expenditures for 'Pharmaceuticals'. The global pharmaceutical market is dominated by the US (see, e.g., Hu et al. 2013). Pharmaceuticals is a science-

41 EU refers to the EU15 up to 2003, the EU25 from 2004, and the EU27 from 2007. EU28 data were not available at the time of writing.
42 EU refers to the EU15 up to 2003, the EU25 from 2004, and the EU27 from 2007. EU28 data were not available at the time of writing.

based sector with high entry barriers and a high degree of cumulativeness of the knowledge base, which means that current R&D activities build considerably on expertise gained in previous research (Marsili 2001). This was clearly confirmed when looking at private R&D expenditures in this sector. Firms located in the US invest more in R&D in the pharmaceutical sector than the EU[43], Japan and China together, though the magnitude slightly decreased after 2007. For China the high growth performance observed for 'Chemical Products' was not evident. Only since 2008, did Chinese expenditures seem to have grown more intensively, but still at a lower level than that for 'Chemical Products', which points to the cumulativeness of knowledge in this sector. The EU and Japan show a very similar growth performance. Their growth in this sector between 2000 and 2010 is also markedly higher than that for China.

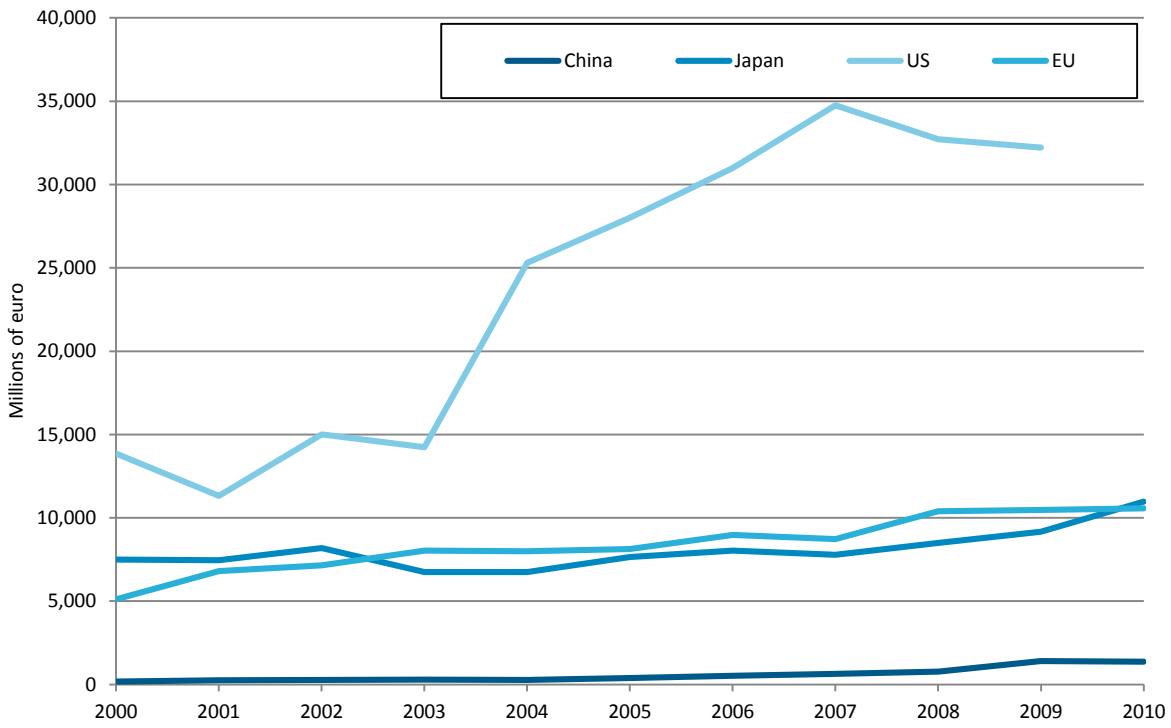

Figure 30. Private R&D expenditures for Pharmaceuticals (2000-2010)[44]

Source: China Statistical Yearbook, Eurostat, OECD, own calculations

43 EU refers to the EU15 up to 2003, the EU25 from 2004, and the EU27 from 2007. EU28 data were not available at the time of writing.
44 EU refers to the EU15 up to 2003, the EU25 from 2004, and the EU27 from 2007. EU28 data were not available at the time of writing.

For the sector 'Computers, Electronics and Optical Products' (Figure 31), some similarities to the sector 'Pharmaceuticals' were detected. The US was found to dominate this sector with respect to R&D expenditures, though a considerable hiatus can be observed between 2001 and 2003. The EU[45] almost caught up with Japan, but private R&D expenditures have remained more or less the same for both since 2007. In contrast, China showed a stable significant growth between 2000 and 2010, approximating the level of the EU in the medium-term.

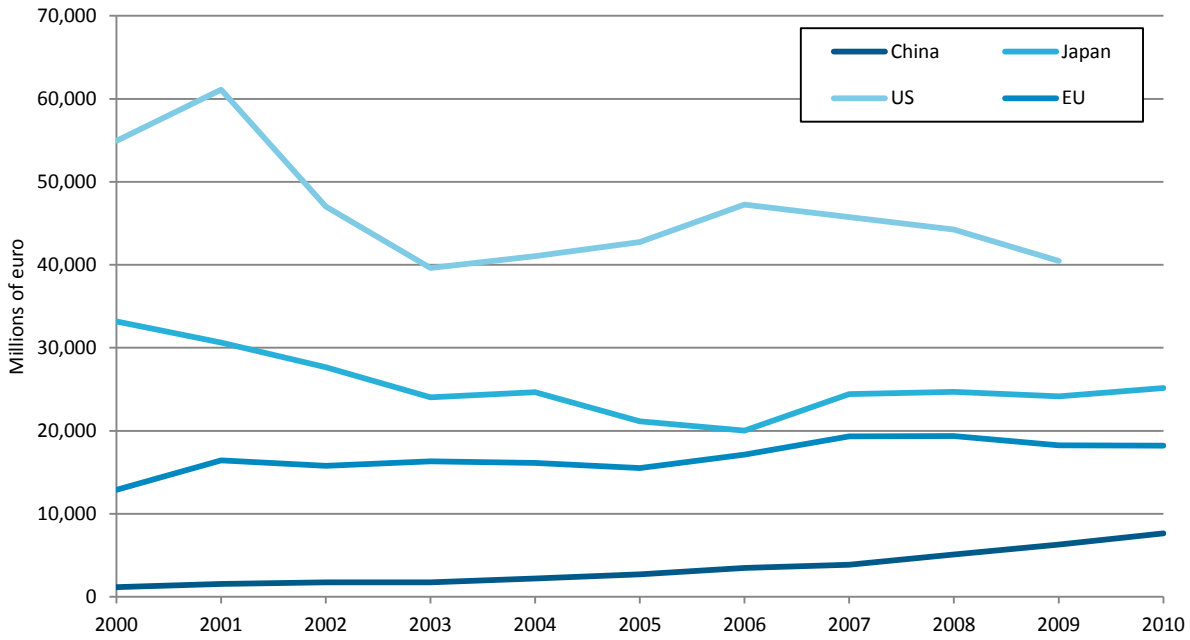

Figure 31. Private R&D expenditures for Computers, Electronics and optical products (2000-2010)[46]

Source: China Statistical Yearbook, Eurostat, OECD, own calculations

A completely different picture was found for the related sector 'Electrical Equipment' (Figure 32). This was the only sector of economic activity out of all sectors under consideration where firms located in China spent more on R&D in 2010 than their competitors located in the EU[47], the US or Japan. In 2006, Japan - though already decreasing before this - had the highest R&D expenditures in this sector, but this was followed by a considerable hiatus between 2006 and 2007. While the EU took the role as global leader in terms of private R&D expenditures in this sector in 2007, China overtook the EU in

45 EU refers to the EU15 up to 2003, the EU25 from 2004, and the EU27 from 2007. EU28 data were not available at the time of writing.
46 EU refers to the EU15 up to 2003, the EU25 from 2004, and the EU27 from 2007. EU28 data were not available at the time of writing.
47 EU refers to the EU15 up to 2003, the EU25 from 2004, and the EU27 from 2007. EU28 data were not available at the time of writing.

2009, showing a tremendous growth between 2005 and 2009. US expenditure did not change significantly over the period putting it in fourth position just below Japan in 2009.

However, it is important to note that private R&D expenditures in this sector were generally lower than in other sectors, such as pharmaceuticals or computers. Additionally, Chinese sectoral R&D data is not completely comparable to that of other countries[48]. Nevertheless, the fast growth of China may be to a large extent related to the establishment of Chinese firms as global players in the telecommunications sectors. The telecommunications manufacturers ZTE and Huawei are notably the most important ones in this context, also showing a considerable portfolio to local suppliers for high-level assembling in the Guangdong region (Shenzen).

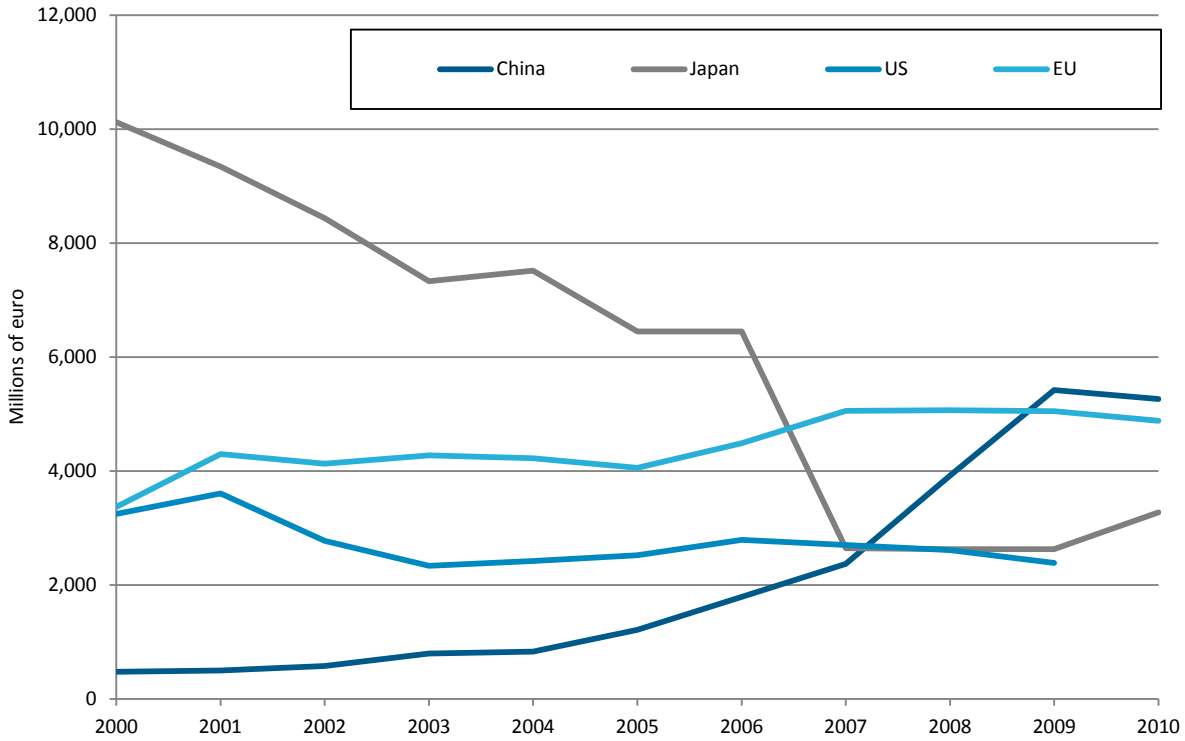

Figure 32. Private R&D expenditures for Electrical Equipment (2000-2010)[49]

Source: China Statistical Yearbook, Eurostat, OECD, own calculations

48 Chinese data on sectoral R&D expenditures is not classified along the NACE 2.0 sectoral classification but uses a national classification system. The transformation of Chinese data into NACE 2.0 leads to large amounts of R&D being allocated to electrical equipment but very low Chinese R&D expenditures in Computers, Electronics and Optical Products. However, the patent analysis performed in the following section reveals that Chinese R&D in both of these sectors grew at a similar pace over the last years. Therefore the results on R&D expenditures of these two sectors have to be interpreted carefully, especially the allocation of a firm to one of these two sectors seems to be treated differently in China compared to the EU, US and Japan. However, these two sectors can be summarized as electrical and optical equipment when needed and results for this broader sector seem to be much more reliable.

49 EU refers to the EU15 up to 2003, the EU25 from 2004, and the EU27 from 2007. EU28 data were not available at the time of writing.

China's development in the sector 'Machinery and Equipment' (Figure 33) was comparable with overall Chinese development. A considerable growth performance was observed after the year 2003. The EU[50] countries devoted most funds to this sector, followed by Japan and the US, with Japan showing an increasing trend since 2009, while investments of US firms decreased after 2006. Also for the transport related sectors (Figure 34 and 35), China showed more or less the same constant growth pattern over the time period 2000-2010. Concerning 'Motor Vehicles' (Figure 34), it is worth noting that R&D expenditures of firms located in the US significantly decreased over the observed time period. Starting as global leader in the year 2000, the US was overtaken by the EU and Japan in 2002 and 2003, respectively. The EU and Japan showed similar growth patterns over the observed periods. China has been closing the gap with the US which can be assumed as likely to continue in the near future. Given the trend to be observed from Figure 34, China may overtake the US within a few years.

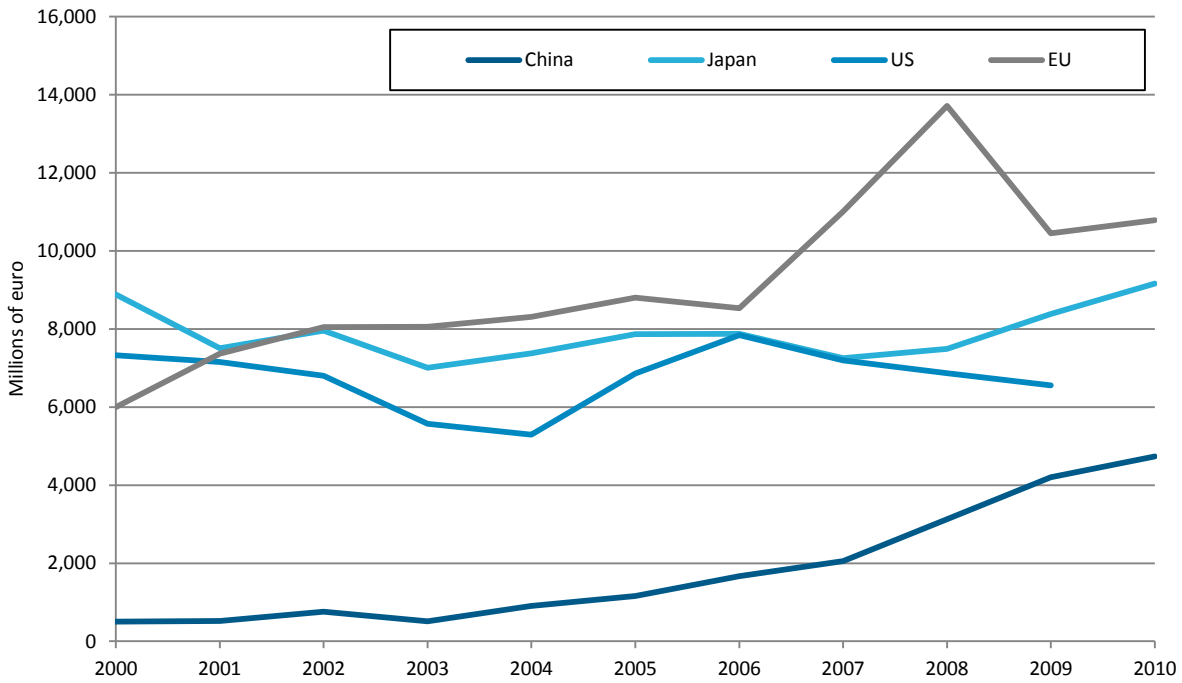

Figure 33. Private R&D expenditures for Machinery and Equipment (2000-2010)[51]

Source: China Statistical Yearbook, Eurostat, OECD, own calculations

However, while the US showed a significant decrease in private R&D expenditures for 'Motor Vehicles', the complete opposite development can be observed for the sector 'Other Transport

50 EU refers to the EU15 up to 2003, the EU25 from 2004, and the EU27 from 2007. EU28 data were not available at the time of writing.
51 EU refers to the EU15 up to 2003, the EU25 from 2004, and the EU27 from 2007. EU28 data were not available at the time of writing.

Equipment' (Figure 35), mainly comprised of R&D in aeronautics and in boats and ships. While the US was the global leader in this sector over the whole time period, a tremendous growth is observed between 2007 and 2008 for China. Private R&D expenditures nearly doubled in this year, mainly related to extensive investment in aeronautics. As mentioned above, China showed a stable growth pattern, as did the EU[52]. While the growth in the EU was, as for the US, driven by high growth rates in aeronautics, the driving force behind the growth of Chinese R&D expenditures in 'Other Transport Equipment' was huge R&D investments in 'Ships and Boats'. In 2010, 'Aeronautics' only accounted for 20% of the total Chinese R&D expenditures in 'Other Transport Equipment'. This was well below the equivalent value for the EU for which 88% of R&D expenditures in 'Other Transport Equipment' were spent on the subsector of 'Aeronautics'. The R&D priorities within this sector are therefore clearly different in China compared to the EU or US.

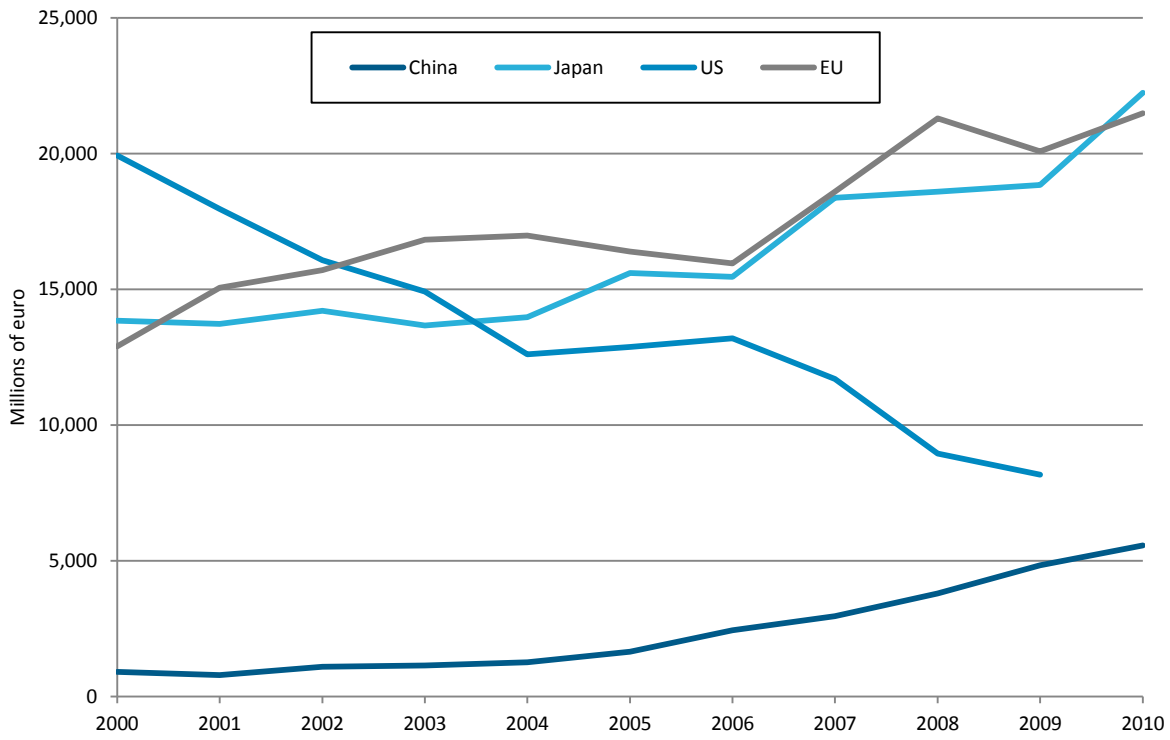

Figure 34. R&D Expenditure in Motor Vehicles (2000-2010)[53]

Source: China Statistical Yearbook, Eurostat, OECD, own calculations

52 EU refers to the EU15 up to 2003, the EU25 from 2004, and the EU27 from 2007. EU28 data were not available at the time of writing.
53 EU refers to the EU15 up to 2003, the EU25 from 2004, and the EU27 from 2007. EU28 data were not available at the time of writing.

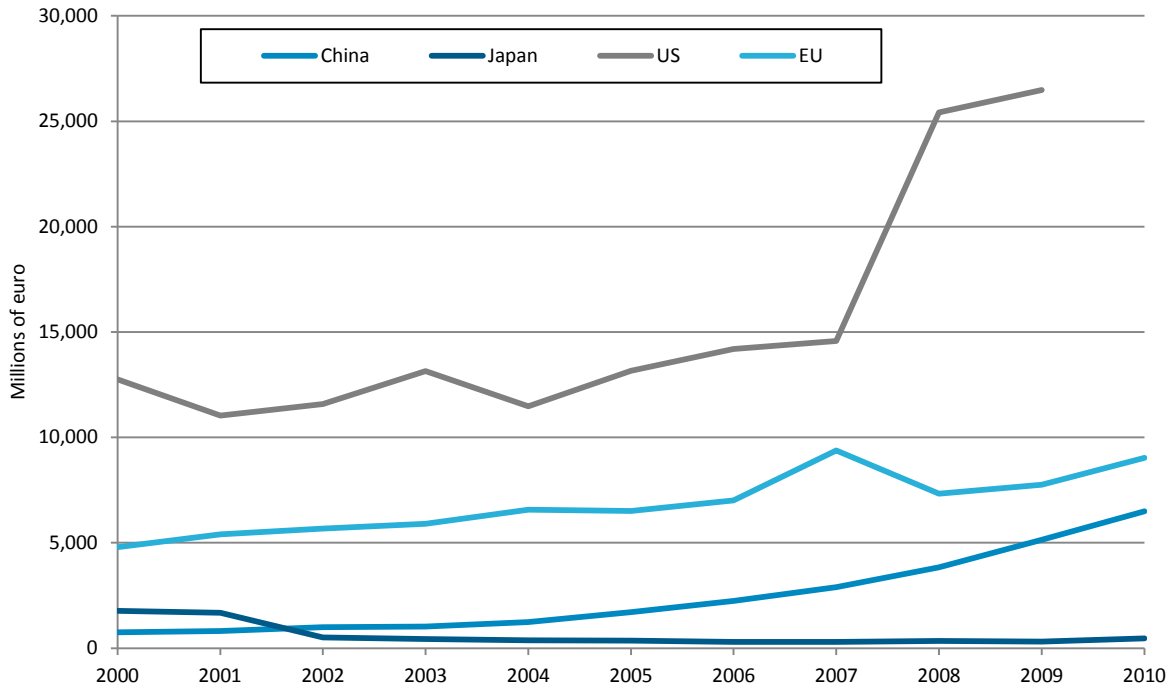

Figure 35. Private R&D expenditures for Other Transport Equipment (2000-2010)[54]

Source: China Statistical Yearbook, Eurostat, OECD, own calculations

Patent output in selected sectors and cross-cutting technologies

To provide a more detailed picture of the trends observed above, the remainder of this section is devoted to China's patent output in a global perspective. More information on China's patenting activities at the sectoral level is provided in the Annex.

Figure 36 presents the share in global PCT patenting for the year 2011 in the eight sectors and three cross-cutting technologies under consideration (see Section 3.1), while Figure 37 depicts the number of patent applications in China relative to the EU[55]. First, it is possible to observe the growth in overall patenting followed by an overview of sectoral priorities in Chinese patenting, again in comparison to the US, the EU27, Japan and RoW.

54 EU refers to the EU15 up to 2003, the EU25 from 2004, and the EU27 from 2007. EU28 data were not available at the time of writing.
55 EU refers EU27.

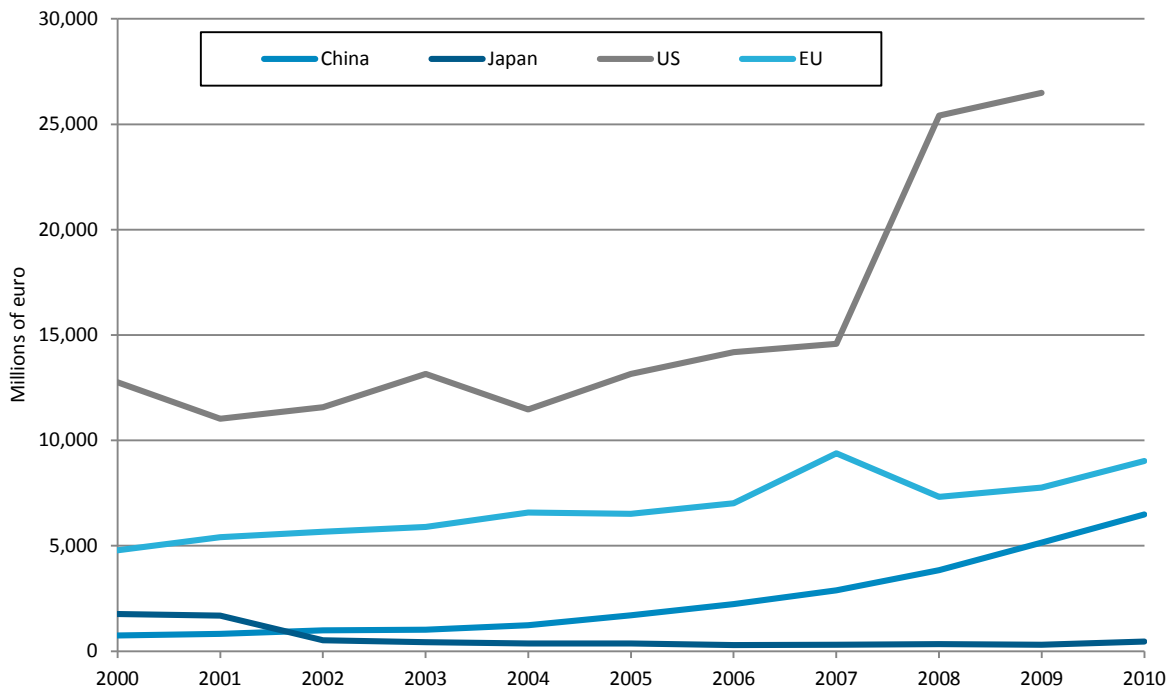

Figure 36. Share in global PCT patenting by selected sectors (2011)

Source: OECD, REGPAT database, January 2013, own calculations

The results show that in 2011, China had a specialisation in the sector 'Computers, Electronics and Optical Products' as well as 'Electrical Equipment', holding a share of more than 10% of global PCT patents in these sectors. The high patenting activity in these sectors can be mainly explained by the high number of patents related to Information and Communication Technologies. China hosts two of the largest global players in telecommunications, the multinational enterprises ZTE and Huawei, accounting for more than 30% of patents in these sectors and also belonging to the top patenting actors worldwide. The average patenting intensity was around 5% to 7% share in PCT global patenting and was found for the remaining sectors: 'Chemical Products', 'Pharmaceuticals', 'Fabricated Metal Products', 'Machinery and Equipment', 'Motor Vehicles' and 'Other Transport Equipment'.

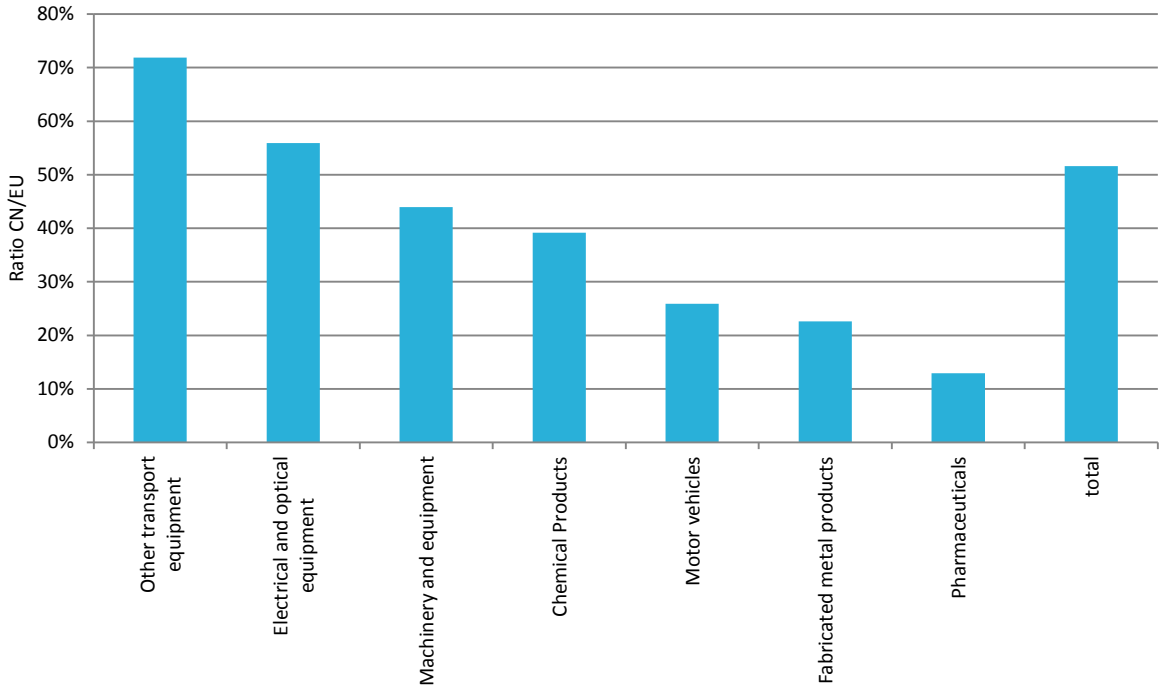

Figure 37. Patent applications in China relative to the EU (2011)[56]

Source: OECD, REGPAT database, January 2013, own calculations

A lower global share was identified for the three cross-cutting technologies, revealing a share in global patenting of about 5% and lower in 2011. While in 'Biotechnology' and 'Environmental Technologies', the share was about 5%, 'Nanotechnology' showed the lowest value with about 2% world share. This is rather surprising since China has a high publication intensity in the field of Nanotechnology (see Chapter 2). In the scientific domain, the increase in publishing may be explained by extensive government initiatives to support basic research in this field. As for patenting, the comparably low patenting intensity may be, on the one hand, explained by the lack of rather large private firms that patent in this area, and, on the other hand, it may be the case that large firms, such as ZTE or Huawei choose to patent in other IPC categories than Nanotechnologies.

In contrast, strengths of the EU27 in terms of patenting sectors appear to be 'Fabricated Metal Products', and the transport related sectors such as 'Motor vehicles' and 'Other Transport Equipment'. The US and RoW showed a particular high patenting activity in 'Biotechnology' and 'Nanotechnology', and Japan for 'Electrical Equipment' and 'Environmental Technologies'. However, to get a deeper insight into the development of patenting activities in these sectors and cross-cutting technologies, a

56 EU refers EU27.

sector-specific view is provided in the Annex investigating the number of PCT patent applications for each sector under consideration for the years 1990-2010.

To sum up, patent as well as R&D expenditure data are witness to a profound change in the technological capacities of Chinese enterprises, universities and research organisations during the last 10-15 years. On the one hand, input and output in terms of R&D expenditures and patents has increased considerably, although China still lags behind the US and the EU in these indicators. On the other hand, there is a considerable specialisation visible in R&D as well as patent data, with strengths in electronics, telecommunications, and transport equipment.

4. China's STI policies and international strategy

4. China's STI policies and international strategy

This chapter of the report describes the main STI policies and their implementation and provides opinions on the main STI issues and future prospects gathered from desk research, project survey and interviews. It is divided into the following sub-sections:

- Sub-section 4.1 – Overview of STI Policies - the main trends in S&T and Innovation policy, and the likely future prospects.
- Sub-section 4.2 – Overview of STI funding - the main STI funding instruments.
- Sub-section 4.3 – Industrial and indigenous innovation policy and funding – policies, funding and issues, including modes for STI development, and consequences for foreign firms.
- Sub-section 4.4 – Human capital policies and funding – policies, funding and issues.
- Sub-section 4.5 – Research and technology infrastructure - policies supporting this area and their role in improving enterprise-research collaboration.
- Sub-section 4.6 – International cooperation strategy – policies and their implementation, in particular with the EU; patterns for different stakeholders and role in developing STI capabilities.

4.1. Overview of STI policies

This sub-section covers the main trends in Chinese STI policies including the current and likely future priority areas. Firstly, core national STI policies are summarised. Supporting and regional policies are also outlined. Finally, the main STI policies issues are analysed.

4.1.1 Core national STI policies

The current main guiding policies for Science, Technology and Innovation include:

- Medium and Long Term S&T Development Plan 2006-2020;
- Five -Year-Plans for Science and Technology Development (current plan 2011-2015).

Medium and Long Term S&T Development Plan 2006-2020 (MLP)[57,58]

This plan aims to transform China into an innovative society by 2020. Achievement is assessed by four main indicators: R&D as a percentage of GDP greater than 2.5%, advances in S&T contributing at least

57 Medium and Long Term S&T Development Plan 2006-2020, State Council, http://www.gov.cn/jrzg/2006-02/09/content_183787.htm (in chinese). Last accessed on 14th May 2014.
58 Medium and Long Term S&T Development Plan 2006-2020, summary information, ERAWATCH (in English).

60% to economic growth, reliance on foreign technologies reduced to less than 30%, and a rank among the global top five countries in terms of patenting and scientific publication citations.

Grand challenges are recognised as key concerns with challenges in environment, energy, agriculture, employment and indigenous innovation capabilities being considered as of highest importance. For this breakthroughs are required in biotechnologies, ICT, new materials, advanced manufacturing, renewable energy, marine science, laser technology, and aerospace technologies.

The plan seeks to encourage indigenous innovation through government procurement of high-tech equipment and products and includes actions for stimulating greater R&D investment in R&D performing firms, fostering the establishment of new indigenous R&D performing firms, reducing the firms that do not perform R&D yet, increasing extramural R&D carried out in cooperation with the public sector and increasing R&D in the public sector.

The plan is further detailed in five-year plans. The current plan is described below.

Twelfth Five -Year-Plan for Science and Technology Development 2011-2015[59,60]

Promoting indigenous innovation and the contribution of S&T to societal challenges to address energy and environmental constraints, an aging population, and an unbalanced and unsustainable development pattern are the two key axes of Chinese innovation policy evident in this plan.

Achieving this will involve developing important emerging industries and technologies. Basic science and technology will also be addressed through infrastructure improvements and cross-disciplinary research through six national key science research projects.

The plan does recognise current weaknesses in the innovation system including government micro-management in enterprise activities, lack of policy transparency and ineffective intellectual property law enforcement, among others (MOST 2011). Following the publishing of this plan some areas of weakness have been addressed in further policy documents and activities. For example, in July 2012, the State Council held a conference on "deepening reform to accelerate national science and technology innovation system view", to establish a national innovation survey system. Also, in March 2013 the 12th National People's Congress outlined the strategic document "**Further reform of the S&T system and build enterprise-centred innovation system**," released by the State Council in 2012.

59 Twelfth Five -Year-Plan for Science and Technology Development 2011-2015, State Council, http://www.most.gov.cn/mostinfo/xinxifenlei/gjkjgh/201107/t20110713_88230.htm (in chinese). Last accessed on May 14th 2014.
60 Twelfth Five -Year-Plan for Science and Technology Development 2011-2015 Summary, ERAWATCH (in English).

This policy is designed to strengthen "Industry-University-Research" linkages, and foster research and innovation capacity in the business sector. Further, early in 2013 MOST began drafting the revision of The Law of Promoting Technology Transfer which is expected to reflect the market-based relations between universities and industry in technology transfer. Finally, in November 2013, MOST published a draft report on a National Innovation Survey to be used to monitor innovation indicators.

Future research priorities

In addition to the previously described long-term policy documents, other long-term research visions include "Technological Revolution and China's Future-Innovation 2050"[61], published by CAS as a roadmap for China's S&T development. Two further roadmaps on the future direction of Nanotechnology and major Cross-frontier Technology also exist. In addition, those interviewed in the context of this study considered that the future focus of S&T funding should be on emerging technological areas, emerging industries and the energy and health sectors.

4.1.2 Supporting policies

Other policies that support different aspects of the abovementioned STI policies, will mostly be discussed further in other sub-sections of this chapter. They relate to:

- Industrial or indigenous innovation e.g. the Development Plan of National Strategic Emerging Industries during the 12th Five-Year-Plan Period (2011-2015), the National Plan for Building Indigenous Innovation Capabilities in the 12th Five-Year-Plan Period (2011-2015) as well as the plans for the development of specific industries (see section 4.3);
- Human capital e.g. the National Outline for Medium and Long-term Talent Development Plan (2010-2020) and the National Plan for Medium- and Long-term Educational Reform and Development (2010-2020) (see section 4.4);
- STI infrastructure e.g. the National Medium- and Long-term Plan for Building Key Science and Technology Infrastructure (2012 - 2030), the 12th Five-year Plan for National High-tech Parks (2011-2015) and the 12th Five-year Plan for National High-tech Business incubators (2011-2015) (see section 4.5);
- International cooperation e.g. the EU-China 2020 Strategic Agenda or China's recent policy paper on the EU "Deepen the China-EU Comprehensive Strategic Partnership for Mutual Benefit and Win-win Cooperation" (see section 4.6);

61 Technological Revolution and China's Future-Innovation 2050, Chinese Academy of Science, June 10, 2009, http://english.bic.cas.cn/NE/200906/t20090619_7263.html: Last accessed on May 16th 2014.

- Intellectual Property e.g. the Promotion Plan for the Implementation of the National Intellectual Property Strategy in 2013 (see section 5.6).

4.1.3 Regional policies

Regional governments (provinces, municipalities) in China are granted a high degree of autonomy for regulating and managing the local economy and society. Sub-national governments contribute about a half of the total government investment in R&D.

The distribution of investment in research in China is concentrated in the east along the coast, which performs more than two thirds of China's research activities. Those questioned in the context of this to this study indicated that it was still hard for companies that do not locate along the coast or in the major cities, to obtain funding from the government. There are efforts to address these disparities. For example, in 2012, the Ministry of Education released the **Revitalization Plan for Higher Education Institutes in Mid- and Western China (2012-2020)**[62].

At the same time, the regions where STI activities are most intense are often used as testing beds for innovation policies. For example, the **Framework for Development and Reform Planning for the Pearl River Delta Region (2008-2020)**[63] aims to upgrade existing low-end manufacturing and stimulate modern service industries testing a more open innovation system based on innovation platforms.

4.1.4 Main STI policy issues

This section discusses some of the main STI issues including opinions from desk research, the project's survey and interviews where relevant.

In 2010, a report by UNESCO on China's STI system, highlighted issues such as strengthening protection of IP rights; overcoming financing difficulties that support small and medium enterprise-driven innovation; improving cooperation processes among those main organizations charged with supporting China's innovation agenda, including enterprises, universities and research institutions;

62 http://news.nost.org.cn/2013/06/new-education-plan-10-billion-rmb-investment-in-100-local-universities-in-midwest-china/ Last accessed June 2014.
63 http://www.provost.cuhk.edu.hk/prvo/provost_media/academic_initiatives/PDR_Framework_Eng.pdf. Last accessed June 2014.

and putting further investment in basic research[64](UNESCO, 2010), which it would appear to continue to exist, though some progress has been made in recent years.

In 2012, the World Bank Report "China 2030: Building a Modern, Harmonious, and Creative Society"[65], identified the following weaknesses in the current innovation policies: the weak incentives for government-funded research institutes to work with commercial users of new technologies; the need for greater enforcement of intellectual property rights laws; insufficiencies in the evaluation of government R&D expenditures, among others. This report recommended that government should help build countrywide research networks to reduce disparities between the coastal and the inland areas and even link to global networks. It also recommended fostering investment by high-tech multinational corporations in R&D facilities, and the establishment of public technology platforms to provide companies (particularly SMEs) with access to laboratory, metrology, testing, and certification facilities. Higher education reform was also a key area recommended for reform, particularly in terms of giving greater autonomy to institutions while, at the same time, strengthening ethical standards in research. Interaction of higher education institutions with employers was encouraged to ensure that curricula meet industry needs. In regard to increasing the share of basic research it suggested entrusting sufficient funding to a few institutions with proven high-level of performance, and maintaining that funding over a long period.

The progress made in addressing the serious lack of investment in basic research has also been referred to in another recent study[66] (China-United States Exchange Foundation, 2013), which comments that the implementation of the "Knowledge Innovation Project" and the "Construction of World-class Universities" initiative, have enabled China's basic research to make significant progress. Even so, in January 2014, in the context of a mid-term review of Chinas MLP, as an external expert, Denis Simon, of Arizona State University, continued to recommend greater emphasis and support for basic research[67]. Other recommendations, by Denis Simon, in the context of the MLP review, included better financial resources management, especially in terms of ensuring greater accountability for

64 UNESCO Science Report 2010: The Current Status of Science around the World, United Nations Educational, Scientific and Cultural Organization, Paris, France, 2010.
65 China 2030: Building a Modern, Harmonious, and Creative Society, World Bank, 2013
66 US-China 2022: Economic Relations in the Next 10 Years", Chapter 12 Science and Technology Cooperation, China-United States Exchange Foundation, 2013, http://www.chinausfocus.com/2022/wp-content/uploads/Part-02-Chapter-122.pdf
67 https://asunews.asu.edu/20140129-simon-china-innovation-strategy

grant monies received from the government. It would appear that this is an issue already being addressed. Pilot reporting began by MOST in 2013[68].

Finally, in a recent article in the Guardian[69], Cao Cong, of the School of Contemporary Chinese Studies, University of Nottingham, cited a number of current issues with the STI system in China. One of those mentioned included the need for greater coordination between the various government agencies with responsibility for science, technology and innovation. This is an issue that the government has tried to address in the establishment of its National Technology Innovation Project Coordination Group including 15 ministries, among which NDRC, MOST, and MOF and the National Development Bank in May this year.

4.2. Overview of STI funding

This section includes R&D funding instruments, incentives directed at industry and analyses the opportunities and barriers of this funding for international cooperation.

4.2.1 R&D funding

The major funding agencies in China are the Ministry of Science and Technology (MoST), the National Natural Science Foundation of China (NSFC), and the China Scholarship Council (CSC) affiliated to the Ministry of Education (MoE). The Chinese Academy of Sciences (CAS) also has programmes to support the researchers at its institutions in R&D activities including international collaboration. More details on these instruments can be found in documents provided by the EU FP7-funded project ChinaAccess4EU (www.access4.eu/China/). This report will list the main programmes following this brief introduction.

In addition to the above, there are also several regional agencies providing science and technology funds. The major funding agencies include Beijing Municipal Commission of Science and Technology (BMCST), Science and Technology Commission of Shanghai Municipality (STCSM) and Guangdong Provincial Department of Science & Technology (GPDST). Each of these agencies has special programmes dedicated to international cooperation.

68 http://www.most.gov.cn/xinwzx/xwzx/twzb/kjbgfwxt/twzbwzsl/201403/t20140304_112124.htm (in Chinese). Last accessed on 20th May 2014.
69 The science and innovation challenge for China's new leaders, Cao Cong, October 2013, http://www.theguardian.com/science/political-science/2013/oct/08/science-innovation-china-leaders. Last accessed on 20th May 2014.

Further, in 2012, the "Innovation Talent Promotion Project" was launched. This is a joint initiative of seven central ministries with the goal of cultivating world-class scientists, engineers and business leaders in China. The Chinese Academy of Agricultural Sciences (CAAS) has also recently launched the **Chinese Agricultural Science and Technology Innovation Programme (ASTIP)** for 2013-25 to address important agricultural issues in China, such as breeding, animal disease control and quality standards on agricultural products, which will include international cooperation from 2016.

MoST

MoST is a ministry of the Chinese government that coordinates science and technology activities in the country. MoST is the major funding agency of the central government that supports several national level science and technology programmes. Its funding programmes are as follows:

1. National Basic Research Programme (973 Programme) - open to European researchers if working at a Chinese host organization, focuses on basic research;
2. National High-Tech Research and Development Programme (863 Programme) – officially open to European participation, focuses on pre-commercial high-tech projects;
3. National Key Technologies R&D Programme – not open to EU participation, promotes technical upgrading and restructuring of industries;
4. National S&T Major Projects – not open to EU participation, currently 13 projects operating on their own budgets as well as an umbrella scheme pooling funds from other programmes;
5. Agriculture S&T Achievement Industrialisation Fund – not open to EU participation, supports the commercialization of mature agricultural technologies;
6. National New Products Programme - open to EU participation with a Chinese partner, for new technologies, with indigenous IP, high impact or adopting international standards;
7. National Soft Science Research Programme – not open to EU participation, aims to provide consultancy to the governmental decision makers;
8. International S&T Cooperation Programme (ISTCP) - supports Chinese scientists in international research activities, covers projects under multilateral and bilateral agreements;
9. EU-China SME energy conservation and emission reduction research collaboration fund – for SMEs registered in China with established EU partnerships in energy conservation and emission reduction technologies;
10. Torch Programme – funding for building more than 50 national high-tech zones across China.

NSFC

The current Development Plan of the National Science Foundation of China for 12th Five-Year Period (2011-2015)70,71 has defined eight research areas for funding across a broad range of scientific disciplines including management science. The plan mentions the following funding programmes:

1. General Programme - to promote the development of natural science disciplines and to stimulate academic innovation, research topics are selected freely within the scope of NSFC;
2. Key Programme - frontier research, innovation resources integration and key scientific breakthroughs, topics are structured according to the Five Year Plans;
3. Major Programme - scientific issues with strategic significance in China's basic research;
4. Major Research Plan - forms groups of projects and coordinates with other programmes;
5. International Collaborative Research projects – open to EU participation, basic research.

NSFC also has the following programmes funding human resources (see section 4.4.) as well as funding for particular activities related to Science and Technology including:

- Special Fund for Basic Research on Scientific Instruments- open to researchers in China, supporting indigenous innovation and manufacturing capabilities in scientific instruments;
- Programmes of Joint Funds, the Programme for Public Understanding of Science;
- Special Fund for Scientific Activities for Teenagers;
- Special Fund for Key Academic Journals;
- Programme for International (regional) Academic Conference and Exchanges.

CSC

CSC is a non-profit institution affiliated to the MoE. It offers financial support to Chinese citizens studying abroad and to international students and scholars studying in China (see section 4.4).

CAS

CAS is currently guided by a strategy entitled "Innovation 2020"[72]. It has the following programmes funding human resources at its institutions (see section 4.4.): Einstein Professorship Programme; Fellowships for Young International Scientists; CAS 100 Talent Programme; CPCCC 1000 Talent Plan; and CAS Visiting Professorships.

70 Development Plan of the National Science Foundation of China for 12th Five-Year Period (2011-2015), National Science Foundation of China, 2012 (in Chinese), http://www.nsfc.gov.cn/nsfc/cen/bzgh_125/index.html. Last accessed May 2014.
71 Development Plan of the National Science Foundation of China for 12th Five-Year Period (2011-2015), Summary, ERAWATCH.
72 Chinese Academy of Sciences. http://english.cas.cn

4.2.2 Incentives directed at industry

This sub-section includes the policy instruments available for financing R&D and innovation, as well as the current conditions for private funding including banking, venture capital and angel investment.

Government Financing

Among the different government funding programmes available for companies, it is important to highlight the Innovation Fund for Small Technology-based Firms - InnoFund; and the availability of tax incentives for high-tech and new-tech enterprises located in specific areas such as Science parks.

InnoFund[73] (Innofund, 2014) is run by MOST and MOF and is aimed at SMEs focusing on high-tech R&D. The Chinese equity in the firm must be more than 50% and priority is given to high-tech and new enterprises as well as start-ups founded by overseas returnees. It provides subsidized loans, which in 2012, totalled 4.37 billion RMB (0.52 billion Euros -1€ = 8.47 RMB).

Tax incentives are provided to high-tech and new-tech enterprises. They are taxed at a rate of 15% instead of 25% and are entitled to "2-year tax exemption and 3-year 50% deduction" if located in stipulated areas such as Science Parks[74] (ERAWATCH, 2013). In 2013 discussions about the use of science and technology related incentives, the recommendation was for an expansion of this policy[75].

The government is still considered to be the main player in the financing of innovation in China, according to this study's findings. It was pointed out that a large proportion of STI funding goes to large SOEs and universities/institutions and not private companies. The current situation with SME financing has been described in the China SME Finance Report 2013[76](Shi, 2013). Although there are government funding programmes to support companies, some interviewees commented that there is still a lot of bureaucracy to obtain funds and that the low level of funding granted per project does not compensate the effort required to obtain it. It was also stated that a lot of limitations still exist for foreign companies. Nevertheless, it was pointed out that there are special incentives for foreign owned Chinese companies that want to start new businesses (e.g. access to buildings and tax refunds).

73 Innofund, http://www.innofund.gov.cn/. Last accessed 18th May 2014.
74 ERAWATCH COUNTRY REPORT 2012: CHINA, ERAWATCH, 2013.
75 http://www.most.gov.cn/tpxw/201311/t20131111_110282.htm (in Chinese). Last accessed on 20th May 2014.
76 China SME Finance Report 2013, Shi Jian Ping, Mintai Institute of Finance and Banking / Central University of Finance and Economics (CUFE).

Bank Financing

State-owned banks in China dominate the financial system, providing loans at better rates to SOEs over SMEs, which suffer credit shortages, particularly for R&D businesses [77](Kirsten Bound, 2013). SMEs account for around 20-25% of bank loans. Therefore, many SMEs still do not rely on bank financing and prefer profit-based funding or trusts, credit guarantees, micro-credit companies and pawn shops. As of the end of 2012, the number of microfinance companies had reached 6,080, an increase of 2,000 or 41.99% from the end of 2011 and pawning enterprises reached 6,084, a year-on-year increase of 16.20% (China SME Finance Report 2013). To overcome this, the China Banking Regulatory Commission (CBRC) has established a set of rules aiming to incentivise the banks to finance SMEs. Some progress has been made in this direction. In 2006, over 50% of bank loans were made to large corporations[78] (Mckinsey, 2013). By 2011, the same source shows that this had decreased to 39%, with predictions of 33% by 2016.

There is also a lack of financing of innovation activities and new ventures by banks. This is also confirmed by the STI China project findings. Perhaps the situation is beginning to change. One evidence of this could be the foundation SPD Silicon Valley Bank in August 2012, as China's first bank committed to serving innovative sci-tech enterprises. This bank is collaborating with SPDB Shanghai Branch, Shanghai Re-guarantee Co., Ltd and the Minhang District Government to provide credit services to technology and innovation companies in the Minhang District[79]. Also, as of the end of 2012, 18 commercial banks had established a total of 40 various credit franchises and specialty branches in the Zhongguancun National Innovation Demonstration Zone. One final point to note is that banks mostly do not offer loans to foreign companies.

Venture capital in China

Venture capital (VC) indicators have been discussed in Chapter 2 of this report. There has been an overall increasing trend in investment with declines in 2009 and 2012 and an overall peak in 2011[80] (EY, 2013). 2013 saw some recovery from the 2012 decline. Recently technology stocks have been reported to be increasingly popular[81] (Crunchbase, 2014). Other popular sectors include finance, consumer services and biotechnology, since the government is supporting these sectors or

77 CHINA'S ABSORPTIVE STATE Research, innovation and the prospects for China-UK collaboration, NESTA, 2013
78 http://www.mckinsey.com/insights/financial_services/a_new_direction_in_chinese_banking. Last accessed June 2014.
79 http://en.spd-svbank.com/_d276180977.htm. Last accessed June 2014.
80 http://www.ey.com/Publication/vwLUAssets/Global_VC_insights_and_trends_report_2012/$FILE/Turning_the_corner_VC_insights_2013_LoRes.pdf Last accessed June 2014.
81 http://info.crunchbase.com/2014/06/vcs-say-ni-hao-to-chinese-startups/ Last accessed June 2014.

encouraging other investment into these industries[82] (Techsource, 2013). Consumer services is the most prominent sector (EY, 2013).

The government has begun to see VC as essential to encouraging indigenous innovation[83] and is a major contributor to funding along with foreign funds. The establishment ChiNext in 2009, which aims to attract innovative and fast-growing enterprises, especially high-tech firms, is also evidence of this, providing a means for investors to recoup their investments via an Initial Public Offering (IPO) exit[84]. Moreover, two other factors were mentioned by the China SME Finance Report 2013 that may facilitate exits by share transfer - the "New Three Boards Expansion" approved in August 2012, and the launching of the national SME share transfer system in January 2013, as a means to gradually shift small regional pilot programmes of non-listed company share transfers to a national scale. Government Guidance Funds have also seen an increase – totalling 102 in 2012 and raising 29 billion RMB (3.42 billion Euros -1€ = 8.47 RMB)[85]. Most interviewees questioned in this study believed that the risk and uncertainty are increasingly high for investors though and that there is still a lack of capital to support entrepreneurs, particularly for early-stage investment.

Angel Investors in China[86]

With the rapid growth of China's economy and global entrepreneurship, even though the concept of angel investment is relatively new in China, angel investors are increasing. China Business Angels Network (CBAN) was established in 2008 in order to provide funding, business expertise as well assistance to promising early stage companies in China. Moreover, the Angel Investment Network opened a branch in China, providing communication channels between entrepreneurs and investors as well as helping foreign businesses to form partnerships with investors in China. Recently, due to domestic angel investment, many high tech industries and businesses have succeeded in China. According to the interviews conducted by the STI China project, business angel investment is still scarce in China and it was felt that the government could do more to improve this.

82 http://blogs.wsj.com/venturecapital/2014/04/27/china-venture-capital-lures-investors-back-as-fundraising-rises/. Last accessed June 2014.
83 http://www.chinabusinessreview.com/a-new-welcome-for-venture-capital/. Last accessed June 2014.
84 www.szse.cn/main/en/chinext/. Last accessed June 2014.
85 http://www.angelcapitalassociation.org/data/MannieLiu-2013ACASummit.pdf. Last accessed June 2014.
86 http://www.investmentnetwork.cn, last accessed in May 2014.

4.2.3 Challenges and Opportunities for international cooperation

According to the interviews and surveys conducted by the past ChinaAccess4EU project financed by the EC and also comments gathered in this study, international cooperation under Chinese funding programmes presents some challenges that need to be addressed in order to improve reciprocity and European access to Chinese funding. The main challenges identified include:

- Difficulty for EU researchers accessing information on funding opportunities. It is challenging to find accurate and detailed information published in languages other than Chinese, which limits access to Chinese speaking researchers or those with existing Chinese collaborators;
- Short call deadlines. Many calls are published only a few weeks before their deadline (often 3-4 weeks), although some regularity has been noted (i.e. calls published in the same period(s) each year), which can present a significant challenge for international collaborative activities;
- A "good cooperation basis" between applicants is often a precondition for participation. Hence, partners must be able to prove that they have already worked successfully together;
- Lead applicant must normally be Chinese or established in China. Lead applicants are normally individuals and not organisations one-to-one contacts with individuals are very important;
- Low budgets compared to European projects. Personnel costs are not usually funded and financial support is normally restricted to travel and equipment costs;
- Lack of transparency in terms of the selection procedures. It is not usually disclosed whether peer review is implemented or whether the successful projects are selected administratively.

To turn some of these challenges into to opportunities it is necessary to:

- Leverage existing relations with Chinese partners to facilitate access to information and ease the complex application procedures;
- Work with Chinese partners who have already extensive cross-cultural experience, which will also help overcome cultural differences;
- Take advantage of contacts with Chinese scientists in Europe to support the establishment of collaborative activities;
- Source funding from Europe to supplement participation in Chinese programmes (e.g. the new EU-China Research and Innovation Partnership see section 4.6).

4.3. Industrial Innovation, Indigenous innovation and its impact on foreign firms

This sub-section discusses industrial and indigenous policy, the approaches of Chinese companies to STI, such as the modes for technology development / acquisition, the specific cases of SMEs and mid cap companies, state owned enterprises, and large Chinese companies, as well as the impact of indigenous innovation on foreign firms.

4.3.1 Existing industrial and indigenous innovation policy

The Twelfth Five -Year-Plan for Science and Technology Development stresses the promotion of indigenous innovation and the contribution of S&T to societal challenges. It recognises this will require the development of important emerging industries and technologies. Thus, the following main policies were developed:

- Development Plan of National Strategic Emerging Industries during the 12th Five-Year-Plan Period (2011-2015) [87,88]
- National Plan for Building Indigenous Innovation Capabilities in the 12th Five-Year-Plan Period (2011-2015)[89,90]

In addition, individual plans have been published for particular sectors. Those that include a large technology component include, for example: Environmental Protection; Waste Recycling Technology; Solar Power Development; or the Bio-industry Development.

Development Plan of National Strategic Emerging Industries during the 12th Five-Year-Plan

This plan aims to promote and develop energy saving technology, next-generation information technology, biotechnology, high-end equipment manufacturing, new energy, new materials, and new energy vehicle industries to be implemented through 20 projects. The objective is that the value share of these industries should reach 8% of GDP by 2015 and 15% by 2020, while the average annual growth is expected to be above 20%, increasing fiscal and financial policy support, improving technical innovation and human resources policies and encouraging a desirable market environment.

87 Development Plan of National Strategic Emerging Industries during the 12th Five-Year-Plan Period (2011-2015), State Council, 2012, (in Chinese) http://www.gov.cn/zwgk/2012-07/20/content_2187770.htm. Last accessed on 15th May 2014.
88 Development Plan of National Strategic Emerging Industries during the 12th Five-Year-Plan Period (2011-2015), Summary, ERAWATCH.
89National Plan for Building Indigenous Innovation Capabilities in the 12th Five-Year-Plan Period (2011-2015), State Council, 2013 (in Chinese) http://www.gov.cn/zwgk/2013-05/29/content_2414100.htm. Last accessed on 15th May 2014.
90 National Plan for Building Indigenous Innovation Capabilities in the 12th Five-Year-Plan Period (2011-2015), Summary, ERAWATCH.

National Plan for Building Indigenous Innovation Capabilities in the 12th Five-Year-Plan[91]

This plan builds on the document "**Strategies on deepening the reform of the science and technology governance and speeding up the construction of a national innovation system**"[92], which proposes a number of actions to improve linkages between industry, universities, and research institutes. It suggests the provision of R&D tax credit and deductions for SMEs to encourage business R&D. It also highlights the need to facilitate cross-sector planning and S&T resource integration through investing in intermediate agencies, public knowledge platforms and regional innovation planning mechanisms. Further, strengthening IPR enforcement is emphasised to encourage international cooperation.

Thus, the plan, published in January 2013 includes the building of 50 world-class scientific research centres and 100 national engineering centres to provide research infrastructure for universities and industry by 2015. It targets agriculture, manufacturing, emerging strategic industries, energy and transportation. It also addresses: strengthening university-industry linkages, attracting overseas talent, improving intellectual property rights protection and management, and strengthening international cooperation. The document stresses the strategic function of enterprise-driven technology innovation, and the need for a stronger focus on collaborative innovation.

12th Five-year Plan on Environmental Protection[93]

This plan suggests the following industrial policy actions to encourage the development of "green" industries: offering incentives to enterprises engaged in sewage treatment, sludge treatment, desulfurization, denitrification and waste disposal; improving the pollution charging system so that high-pollution production faces higher costs; encouraging bank loan issuance for "green" projects; and increasing the portion of "green products" on government's procurement list.

12th Five-Year Plan Waste Recycling Technology[94]

This plan proposes actions to support the development of technologies to recycle materials/re-use products with priorities including scrap metal, electronic/ electro-mechanical products, and polymers, industrial waste such as fly ash, coal gangue, or gypsum, as well as scale dissolution of smelting waste

91 ERAWATCH Summary, http://erawatch.jrc.ec.europa.eu/erawatch/opencms/information/country_pages/cn/policydocument/policydoc_0015?tab=template&country=cn. Last accessed June 2014.
92 http://www.most.gov.cn/eng/pressroom/201211/t20121119_98014.htm. Last accessed June 2014.
93 China Briefing, December 23, 2011.
94 China Briefing, June 25, 2012.

residue recommending enhanced financing for high-tech enterprises specialized in this area and improved product certification.

12th Five-Year Plan for Solar Power Development[95,96]

This plan highlights various areas in which R&D and innovation are required to support the competitiveness of the solar power technology industry. This includes R&D to improve production equipment used for polysilicon, silicon ingots/silicon wafers, cells and modules, thin-film cells, and power generation applications in order to enhance product quality and PV conversion efficiency, and to reduce energy consumption during production. It also proposes the strengthening of R&D and applications of PV products in industries such as agriculture, transportation, and architecture. R&D priorities for different types of PV technology are pin-pointed including: production techniques for electronic-grade polysilicon; cutting technology for silicon carbide and steel wires; low-reflectivity texturing technology; selective emitter technology; electrode alignment technology; plasma passivation technology; low-temperature electrode technology, and full back junction technology as well as system integration technology for solar PV power generation, among others.

Bio-industry Development Plan[97,98]

The bio-industry is one of China's emerging industries, pin-pointed as of key importance for the country's development. In terms of areas for R&D priorities, this plan highlights the following areas: biotech drug development; high performance medical equipment development; breeding of new varieties including molecular breeding technology and equipment; green technologies, new processes and equipment, biological vaccines and veterinary drugs, biological pesticides, bio-feed, bio-fertilizers and other important agricultural bio-products; bio-ethanol and biodiesel research; and large-scale and high-throughput genome sequencing technology and equipment, massive biological information processing and analysis techniques. The plan also makes proposals for the improvement of support at all levels from industrial innovation incentives (including guidelines for venture capital) to development of standards; improved coordination of actors in the innovation system; training and attracting skilled personnel; as well as market conditions.

95 China Briefing September 19, 2012.
96 http://www.americansolarmanufacturing.org/news-releases/chinas-five-year-plan-for-solar-translation.pdf
97 http://www.gov.cn/zwgk/2013-01/06/content_2305639.htm (Chinese). Last accessed June 2014.
98 China Briefing, January 15, 2013.

4.3.2 Approaches to STI

According to the survey conducted in this study, most respondents mentioned the approach of cooperation with or outsourcing to universities/ CAS institutes as one of the most common means for Chinese companies of dealing with STI. This cooperation would be particularly important for SMEs, since respondents reported that they do not usually have in-house R&D activities. It would appear, according to these opinions, that State-owned enterprises (SOEs) do not contribute greatly to STI. However, SOEs still have a strong presence and are at a prominent position comparing to private business in terms of assets and human capital. In addition, a number of studies, indicate that the prevalent monopoly of SOEs impedes innovation, despite China's effort to privatize them.[99] As to how large Chinese companies use newly acquired dimension for STI development, most respondents mentioned increasing in-house spending on STI and cooperating with higher education and public research organizations. This situation suggests that opportunities for collaboration may exist for European research institutes, however, a number of respondents considered it essential to have the support of intermediary agencies in this process.

The translation of Public R&D investments into high quality scientific results and innovation

According to the survey conducted in the context of this study, the extent to which public R&D investment is converted into high quality scientific results and innovation in China is still rather low or even considered to be very low. Further, when asked to what extent they believe that the research results are utilized by the business sector in China, although some indicated that China has tremendous demand for technology, and government is facilitating the transfer of scientific research outcomes to industries, the majority of the respondents considered that the extent to which the results are used is still low/very low. It is not surprising that one of the key policy areas of action is strengthening the links between research institutions and industry.

According to the report "Chinese Patterns of University-Industry Collaboration" research, Chinese universities collaborate with the industrial organizations in technology and industrial fields via the following mechanisms[100]:

- Technology transfer: This is usually done through license deals for research outputs that generate patents;

99China's Programme for Science and Technology Modernization: Implications for American Competitiveness, 2011
100 Chinese Patterns of University-Industry Collaboration, Asian Journal of Innovation and Policy, 2012

- Collaborative R&D: Direct research projects for or with industrial firms are normally seen as the best way to collaborate on specific solutions with industrial technologies and engineering development and can be promoted by increasing research funds to industries. Joint R&D centres with companies are still immature in Chinese universities. Chinese companies are better at developing and improving existing products rather than doing research and inventing new ones. China is a world leader in second-generation, process and production innovation, but is still weak at novel-product innovation [101](Breznitz and Murphree, 2010). Multi-National Enterprises (MNE) from developed countries recognize China's strong capabilities in science and technology, as they set up new R&D labs near domestic universities or research labs[102](Wang et al., 2011);
- University-run high-tech companies: This occurs when industries operate on industrial production based on the intellectual property or technology resources of the universities. Although university-run high-tech firms are smaller in numbers compared to all companies in high-tech zones, their innovative performances are among the best, being key forces for innovation in China.

EU organizations are in possession of new technologies, which Chinese industry may be interested in making use of, and also often used to providing practical solutions for industry, which may provide an opportunity for collaborative activities. For those not experienced in collaborating with Chinese organizations, intermediary support may be obtained via organizations such as the EU SME Centre, the EU Chamber of Commerce in China or from consultancy companies working in China.

The main mode for technology acquisition

Regarding the main mode for Chinese companies to acquire technology, the majority of respondents to the survey conducted by this study considered importing technology from abroad as the most common mode. In-house development was also widely used followed by joint venture with foreign companies, acquisition of Chinese technology, and collaboration with foreign universities/research institutes. To tackle the challenge of acquiring technology, China launched the Catalogue for the Guidance of Foreign Investment Industries in 2007. It requires technology transfer as a condition for foreign firms to invest in China.

101How China innovatesRun of the Red Queen,CHINA ECONOMIC QUARTERLY, 2010
102 How Chinese firms employ open innovation to accelerate the development of their technological capability, Social Science Research Network Paper, 2011

The main barriers for Chinese SMEs in developing STI

The STI China survey respondents indicated that the high cost of innovation is the most important barrier for Chinese SMEs in developing STI. In addition, insufficient funds, uncertain demand for innovative goods or services, and lack of qualified personnel are also considered to be barriers. According to a recent report, the lack of access to low-cost finance and the significant inefficiencies in their financial supply chain are two major obstacles for SMEs innovating in China [103](MasterCard Worldwide, 2013). The same report recommends subjecting SOEs to market discipline; developing an SME lending focus; reforming the interest rate regime and leveraging innovative solutions to improve financial supply chain efficiency in order to address these. The role of bond markets in promoting the development of financial services has also increased and various regions have begun to explore financial reform, with online financing, as represented by Peer-to-Peer (P2P) lending, generating controversy within the traditional financial sector[104]. One way to overcome the lack of innovation facilities and resources faced by SMEs is to develop "clusters", which can provide a platform for SMEs in a region to share innovation facilities, or production resources. These will be discussed further in section 4.5 on STI infrastructure.

4.3.3 Impact of indigenous innovation on foreign firms

Indigenous Innovation is designed to enhance "original innovation through co-innovation and re-innovation based on the assimilation of imported technologies." This sub-section examines the impact of indigenous innovation policy for foreign firms.

FIEs, European companies in particular have been participating in China's R&D initiatives and contributing to the development of innovative capabilities of the Chinese economy through licensing agreements with Chinese partners and R&D investments. The Chinese government encourages FIEs to offer their expertise and establish R&D centres in China, as well as cooperate with Chinese research institutions jointly participating in key S&T programmes, such as 863 and 973. FIEs which invest in a joint venture (JV) and share its technology with a Chinese SOE would be granted privileged access to the Chinese domestic market and such JV companies enjoy priorities in receiving loans from domestic financial institutions and obtain tax incentives and favourable tariff schemes. It is worth mentioning

103 New Wave of Growth in China Innovation through Developing SMEs, MasterCard Worldwide, 2013.
104 China SME Finance Report 2013, Shi Jian Ping, Mintai Institute of Finance and Banking / Central University of Finance and Economics (CUFE).

that a JV agreement between China and FIEs in terms of technology transfer, including R&D, production, sub-contracting, marketing, after-sale services, and local human resource training, can occur in two ways: production localization and training of engineers. In addition, the government also offers a series of incentives to foreign-invested R&D centers, and such incentives include exemptions of customs duties on imported equipment, business and income tax deductions.

The Chinese government is seeking to minimize the country's dependence on foreign technology and brands through indigenous innovation, aiming at promoting the creation and commercialization of Chinese-owned technology and intellectual property, thus foreign firms see indigenous innovation policies as a means to limit their business opportunities in China's economy. The Chinese governmental organizations at the central and local level have issued indigenous innovation catalogue and procurement policies to give preference to products that are certified as indigenous innovation products (very few products are produced by Foreign Invested Enterprises (FIEs) in China) and introduced incentives such as financing and tax relief schemes to encourage the development and use of indigenous innovation products by Chinese companies. Indigenous innovation policies also increased the patenting of Chinese inventors, especially on utility model and design patents as they were inexpensive and easy to obtain.

According to the project survey, in regard to how the indigenous innovation strategy has been performing since its launch in 2006, most interviewees refer to an improved innovation system. Improvements indicated concern increased collaborative innovation and increasing acknowledgement among firms regarding the need to innovate. On the other hand, the survey conducted in this study found that the indigenous innovation strategy has made access to public procurement opportunities in China more difficult for FIEs, due to barriers to market entry, preferential treatment of domestic firms and products, as well as a higher risk of IPR infringement for foreign firms. Others believe that since the procurement market is rather small compared to other opportunities for EU firms, that it is not a significant barrier.

4.4. Human capital for innovation

Human capital is crucial for the development of an innovation ecosystem. Having acknowledged this fact, the Chinese government has increased investments in education, health care, early childhood development, among others. This sub-section will discuss human resources policies, funding to support human resource development (excluding instruments that are mainly directed at

international collaboration, which will be discussed in section 4.6) and the main issues concerning human capital for innovation.

4.4.1 Human resources policies

In 2010, the State Council published a **White Paper on Human Resources[105],** which summarises the main policy actions that have been promoted to improve human resources development and the mechanisms to train, attract, use and support talented people. The documents that most concern STI include:

- National Plan for Medium- and Long-term Educational Reform and Development (2010-2020);
- The National Outline for Medium and Long-term Talent Development Plan (2010-2020).

National Plan for Medium- and Long-term Educational Reform and Development (2010-2020)[106]

This plan addresses educational reform and improvement at all levels including issues such as equal access, quality, life-long learning, and modernization, among others. Most relevant to human capital development for STI are the strategies and reforms of the vocational and higher education systems. In this respect, the higher profile of innovation and entrepreneurship is worth noting. In May 2010 the government issued "Guidelines for Promoting Innovation and Entrepreneurship Education in HEIs and Self-employment Activities of University Graduates" with the aim to encourage universities to create courses and curricula on creativity, innovation and entrepreneurship. This aspect of entrepreneurship education was then written into the current plan.

With respect to vocational education development, one of the main aims is to encourage a greater cooperation between vocational schools and enterprises and a greater engagement of employers in vocational training such that training more closely meets the needs of industry. The plan mentions incentives for enterprises to invest more in vocational education, or to accept internees. Another important area that the plan aims to address is the uneven level of education between urban and rural areas and between different regions.

With respect to higher education development, the plan mentions the introduction of a "double mentor system" and a postgraduate education innovation plan. Projects 985 and 211, allocating large amounts of funding to certain universities and establishing National Key Universities were referred to

105 White Paper on Human Resources, State Council, 2010: http://english.gov.cn/official/2010-09/10/content_1700448.htm
106 https://www.aei.gov.au/news/newsarchive/2010/documents/china_education_reform_pdf.pdf. Last accessed June 2014.

for continuation, although no new organizations have be added to project 985 from 2011, which currently funds 39 universities.

The National Outline for Medium and Long-term Talent Development Plan (2010-2020)[107]

This plan contains objectives for the enlargement of China's S&T workforce over the next ten years such that by 2020, China will have over 2 million researchers; 4.3 R&D personnel per 10,000 workers; and R&D expenditure per researcher increases from the current €0.05m (RMB0.44m) to €0.12m (RMB1m), approximately on par with the averages in the moderately developed countries.

In terms of Science and Technology personnel the focus will be on improving independent innovative capacity, further reform of the science and technology system in terms of evaluation, intensify the attraction of high-level overseas innovative talent. In this context, the continuation of the 100-Talent Program, Chang Jiang Scholars Program, and National Science Fund for Distinguished Young Scholars was mentioned. Increasing inter-disciplinarity and strengthening industry-university cooperation were also stated as objectives for the coming years.

The plan further includes measures for increasing the number of trained personnel in areas where there are shortages. Fields such as equipment manufacturing, information technology, biotechnology, new materials, aerospace, international business, environmental protection, new energy, communication and transportation, and agriculture technology were highlighted. The introduction of demand forecasting was mentioned as was attracting talent to remote areas.

4.4.2 Funding for human resources development

Funding for human resources development is provided through programmes implemented directly by the Ministry of Education (MOE) or as part of a range of STI funding programmes e.g. those funded by NFSC or CSC (affiliated to MOE). CAS also provides programmes for researchers at its institutions that support human resource development. Further, the Ministry of Human Resources and Social Security has established a RMB 6 billion programme (0.71 billion Euros) with the objective to provide vocational training to high school graduates and migrant workers.

107 http://cfd.seu.edu.cn/s/583/t/2172/73/24/info95012.htm Last accessed June 2014.

MOE

The **Yangtze River Scholar Award Scheme**[108] aims to support the implementation of the National Programme for Long-Term and Medium-Term Educational Reform and Development (2010-2020), and the National Programme for Long-Term and Medium-Term Talents Development (2010-2020) by attracting international talents, promoting existing talent, strengthening school education, and improving the quality of higher education. High education institutions in central and western China will be particularly strengthened. It is also important to note that this programme is open to European researchers.

NFSC

The NFSC development plan for 2011-2015 list the following programmes for supporting human resource development in S&T:

- National Science Fund for Talent Training in Basic Science[109]- aims at fostering practical ability, preferential support to the bases in the western and north-eastern regions;
- Young Scientists Fund[110] - supports young scientists to freely choose their research topics within the funding scope of NSFC to conduct basic research;
- Fund for Less Developed Regions[111] - supports scientists in specified regions to conduct creative research within the funding scope of NSFC, facilitating the construction of the regional innovation system as well as the social and economic development of the region;
- National Science Fund for Distinguished Young Scholars[112] - supports young scholars who have made outstanding achievements in basic research to select their own research directions;
- Science Fund for Creative Research Groups[113]- supports research groups which carry out basic research or applied basic research in China focusing on key research orientations and which have prominent young scientists as pacemakers or backbones;
- Research Fellowships for International Young Scientists (see section 4.6).

108 http://english.jsjyt.gov.cn/news/keynews/folder612/2012/03/2012-03-142378.html Last accessed June 2014.
109 http://www.nsfc.gov.cn/Portals/0/fj/english/fj/pdf/2010/101.pdf, last accessed May 2014
110 http://www.nsfc.gov.cn/Portals/0/fj/english/fj/pdf/2013/051.pdf, last accessed May 2014
111 http://www.nsfc.gov.cn/Portals/0/fj/english/fj/pdf/2011/061.pdf, last accessed May 2014
112 http://www.nsfc.gov.cn/Portals/0/fj/english/fj/pdf/2011/041.pdf, last accessed May 2014
113 http://www.nsfc.gov.cn/Portals/0/fj/english/fj/pdf/2009/081.doc, last accessed May 2014

CSC

The main CSC programmes open to European researchers include the following:

- CHINA/UNESCO - the Great Wall Fellowship - full scholarship programme set up by MOE for candidates recommended by the United Nations Educational, Scientific and Cultural Organization (UNESCO), only available to applicants who come to study as general scholars and senior scholars;
- Chinese Government Scholarship Scheme - established by MoE in accordance with educational exchange agreements or MoUs (memorandum of understanding) signed between the Chinese government and governments of other countries, organizations, education institutions and relevant international organizations to provide both full scholarships and partial scholarships. The programme supports students who come to study in China on undergraduate, postgraduate programmes, Chinese language training programmes, general scholar and senior scholar programmes;
- Distinguished International Students Scholarship - set up by MoE to sponsor outstanding international students who have finished their Bachelor's degrees or above in China and have been enrolled by designated Chinese HEIs (Higher Education Institutions) for higher education or are now doing their Masters or Doctoral degrees in those institutions.

CAS

The main CAS programmes open to European researchers include the following:

- Einstein Professorship Programme - aims to enhance the science and technology links, cooperation and exchange between CAS scientists and respective Einstein Professors and their laboratories, and training of future generations of scientists in China, funds distinguished international scientists actively working at the frontiers of science and technology to conduct lecture-tours in China with a duration of one or two weeks;
- Fellowships for Young International Scientists - aim to facilitate academic exchanges and cooperation between CAS institutes and international institutes and universities, and development of talented scientists by attracting young international scientists to conduct cooperative research at CAS institutes for 12 months.
- CAS 100 Talent Programme - aims to support and invite experts of the following categories to China: overseas talent (Category A); domestic talent (Category B); project-based domestic and overseas talent (Category C); winner of "National Excellent Young Scientist Fund" (Category

D); winner of "Youth 1000 Programme" (Category Y); overseas and domestic talent funded by individual employers (Category Z);

- CPCCC 1000 Talent Plan – aims to attract around 2000 leading individuals under the age of 55, who hold professorships or equivalent positions in renowned foreign universities or research institutes, for a period of 5 to 10 years. Besides this, another initiative was launched in 2011 – The Thousand Youth Talents Programme for Distinguished Young Scholars – which aims to attract around 2000 excellent young overseas scholars, under the age of 40, by 2015[114].

4.4.3 STI Human resource issues

Figures revealed by the Chinese Ministry of Science and Technology illustrate that the number of Chinese researchers is increasing rapidly, it almost doubled in two years (from 1.05 million in 2008 to 2 million in 2010). It is estimated that by 2030, China will have around 200 million college graduates, more than the working population of the United States. The quality of higher education has also made fast progress: in 2003 there were 9 universities in the top-ranked 500 universities of the world, and in 2010 there were 22. There is, however an uneven geographic distribution of talent across the country with a concentration in cities such as Beijing, Shanghai, Shenzhen and Guangzhou. There is also an issue reported by interviewees in the current study of maintaining human capital. This could be justified by often insufficiencies in training plans or even a lack of them, high competition between companies for human capital, particularly in areas of shortage, and the attraction of working abroad.

Returnees have been seen as an important source of knowledge that could help push China´s progress forward. Returnees are believed not only to act as an instrument "to strengthen the nation through science and technology", but also as a valuable linkage to the international scientific community, helping to keep China more connected to the latest scientific advancements. As Hannah Sieber[115] (2013) mentioned in the report "Chinese 'Sea-Turtles' and Importing a Culture of Innovation: Trends in Chinese Human Capital Migration in the 21st century", the knowledge that returnees have acquired has helped close the technological gap between China and the more developed countries. These

114 http://academicexecutives.elsevier.com/articles/china-building-innovation-talent-program-system-and-facing-global-competition-knowledge, last accessed January 2014

115 Hannah Sieber, 2013. Chinese 'Sea-Turtles' and Importing a Culture of Innovation: Trends in Chinese Human Capital Migration in the 21st century, Duke University. Available at: http://dukespace.lib.duke.edu/dspace/bitstream/handle/10161/7560/Hannah%20Sieber,%20Chinese%20Sea-Turtles%20and%20Importing%20a%20Culture%20of%20Innovation.pdf?sequence=1

aspects were also brought to bear in the current study's survey and interviews with interviewees emphasizing the need to increase the incentives to attract returnees.

4.5. Research and technology infrastructure

In the following an overview of the role of the developing research and technology infrastructure, with in particular the avenues offered in terms of cooperation between research centres and firms is presented.

Chinese research and technology infrastructure has been developing rapidly due to the support from the government.

4.5.1 Existing policies

China's latest policy concerning research infrastructure is contained in the document **"National Medium- and Long-term Plan for Building Key Science and Technology Infrastructure (2012 - 2030)"[116,117].** This plan calls for improvement in 7 strategic areas: energy, life science, earth system and environment, materials, particle physics and nuclear physics, space and astronomy, and engineering technology. The document proposes 16 major R&D infrastructure projects until 2015: seabed scientific observation network, validation device for the high-energy synchrotron radiation light source, an accelerator-driven transmutation research facility, a comprehensive experimental facility for extreme conditions, an intense heavy-ion accelerator, efficient and low-carbon gas turbine test equipment, a high-altitude cosmic ray observatory, a future network test facility, a ground simulator for space environment, a translational medicine research facility, a south pole observatory, a high-precision gravity measurement facility, a large-scale low-speed wind tunnel, a SSRF beam-line station, a model animal phenotype and heredity research facility, a numerical simulator for earth systems. The infrastructures are to be open to outside users and the need for increasing international collaboration is emphasised.

There are two current Five-year plans that are also related to research infrastructure and strengthening the link between research institutions and industry, one for High-tech Parks and the other for incubators.

116 National Medium- and Long-term Plan for Building Key Science and Technology Infrastructure (2012 - 2030), State Council, 2013, http://most.gov.cn/yw/201303/t20130306_99983.htm (in Chinese): Last accessed on 15th May 2014
117 National Medium- and Long-term Plan for Building Key Science and Technology Infrastructure (2012 - 2030), Summary, ERAWATCH.

12th Five-year Plan for National High-tech Parks (2011-2015)[118]

This plan aims to accelerate the development of high-tech parks and increase their innovation capacity. The goal is to attract 3,000 overseas high-calibre professionals and establish 15 internationally competitive clusters with annual revenue of over 100 billion RMB (11.8 billion Euros - 1€ = 8.47 RMB). Strategic emerging industries will be prioritised as well as the service sector.

12th Five-year Plan for National High-tech Business incubators (2011-2015)[119]

This plan aims to increase the total number of incubators nationwide to 1,500, of which 500 will be at national-level. It also foresees that more than 30% of national-level incubators will have built business nurseries and accelerators; more than 50% will have the facility to make angel investment; over 60% of the employees will have received training on incubators; 80% will have created public technology service platforms; and 90% will have established a start-up mentor system.

4.3.2 Current academia-industry infrastructures

In spite of support from the government, however, according to interviews conducted by the STI China project team, close links between universities and industries appear to be quite scarce. The gap between universities and industries is one of the main barriers to innovation in China. Incubators /High-tech parks /clusters are types of infrastructures that can foster greater contact and collaboration between these entities. This sub-section will discuss the current status of this type of infrastructure in China.

The Torch Programme started in 1988, aiming to stimulate industrialization of high tech technology, creating incubators and high tech zones. It represents a major institutional effort to support start-ups, and, in 2011, 89 high-tech zones were overseen by this programme, contributing to over a third of the national industrial output (e.g., Zhongguancun Science Park in Beijing) (Bound, 2013) [120].

Incubators are mainly considered as a place for technology transfer coming from universities and research institutes to meet the market by participants in this project's survey and its interviewees. China's first incubator was born in 1987. Now there are a total of 614, of which 197 are certificated as

118 China Science and Technology Newsletter, MOST, January 2013.
119 Science and Technology Newsletter, MOST, February 2013.
120 Micah Springut, Stephen Schlaikjer, and David Chen, China's Programme for Science and Technology Modernization: Implications for American Competitiveness, 2011

national incubators by Ministry of Science and Technology (MoST). The first technology business incubator (TBI) was founded in Wuhan of China, and these have been growing since then. In 2010 there were 896 TBIs in China (China Torch Programme survey[121]). Also, there were 56.382 tenants in TBIs in 2010, providing 1.170.000 jobs. From all of the 36,485 graduated tenants, 80% of the companies survived the market competition, about 600 companies have annual revenues exceeding CYN 100 million, and over 50 companies have successfully executed (Guo et al., 2012).

Interviewees also stated that there are a significant number of science parks in China, but that they are not fully utilized. Many science parks are very far away from the city's downtown, thus not attracting Chinese or foreign staff. However, examples of successful science parks and incubators, provided by those interviewed in the course of this study include: Zhongguancun hi-tech park and the Tsinghua Science Park both located in Beijing, and the Zhangjiang hi-tech park in Shanghai.

Interviewees considered that incubators and parks play an important role in the promotion of innovation clusters, technology transfer, and commercialization of research results in China. In particular, they work as a networking, collaboration and resource-sharing platform for different types of innovators. Clusters are also one way to overcome the lack of innovation facilities and resources faced by SMEs, providing a platform for SMEs in a region to share innovation facilities, or production resources. Cluster strategy has thus become one of the key solutions for policy makers in different countries and SME clusters also have become a hub for researchers to seek cooperation with industry. China is no exception. The clusters are mainly located in the coastal areas where the market system and supporting schemes are more mature than those in other areas. Meanwhile, recently the western part of China has also become a popular place for SME clusters as the government is developing the region[122](Chen, 2006).

Besides incubators and science parks, interviewees also pointed out that other intermediaries facilitating the innovation process include foundations for industry-university joint research and subsidies available at provincial level for cooperation, most of which are for Chinese companies and universities.

121 China Torch Statistical yearbook 2011

[122] SME clusters in China One way to build up innovation capabilities, Xiangdong Chen and Li-li Cao, 2006

4.6. Patterns of international cooperation

The "open door" policy in China has enabled easier access to foreign capital and technologies and spurred its knowledge-intensive activities. Indeed, China has emerged as an important research, development and innovation (R&D&I), player and partner to many countries and organizations around the world. This has led to the large majority of European Member State governments as well as many institutes in Europe to establish concrete science and technology cooperation activities with China such as joint R&D programmes, joint R&D centres or joint PhD programmes. This sub-section explores international cooperation strategy and its implementation, in particular that with the EU. It comments on the role of international cooperation in developing STI capabilities, its patterns for both private and public stakeholders and the role of international researcher mobility in acquiring scientific and technological information.

4.3.1 EU-China R&D cooperation strategy

The partnership between the EU and China has deepened over the years incorporating a greater number of topics. For example, in the area of STI, in 2003 a Framework Agreement for establishing industrial policy dialogue was established[123] (European Commission, 2003), in 2012, the setting-up of the EU-China Higher Education Platform for Cooperation and Exchange was agreed[124], while in January 2014, New EU-China Intellectual Property Cooperation was launched building on two previous projects in this area[125]. The current basis for EU-China cooperation is summed up in the EU-China 2020 Strategic Agenda for Cooperation[126] (European Commission, 2013), which was adopted on 21st November 2013 at the occasion of the 16th EU-China Summit. An important vehicle for STI cooperation recently established is the EU-China Innovation Cooperation Dialogue, whose first meeting took place in November 2013[127]. The meeting acknowledged cooperation progress in areas such as food, agriculture and biotechnology, sustainable urbanisation, and aviation, as well as EU-China cluster cooperation. It was also proposed to strengthen ICT cooperation in key topics such as future telecommunications (5G), smart cities and the internet of things. Furthermore, the setting up

[123] Framework Agreement for establishing industrial policy dialogue, 30 October 2003: http://eeas.europa.eu/china/docs/ipd_291003_en.pdf. Last accessed on 21st May 2014.
[124] http://ec.europa.eu/education/international-cooperation/documents/china/follow_en.pdf. Last accessed on 22nd May 2014.
[125] http://eeas.europa.eu/delegations/china/press_corner/all_news/news/2014/20140116_en.htm. Last accessed on 22nd May 2014.
[126] EU-China 2020 Strategic Agenda for Cooperation, http://eeas.europa.eu/china/docs/eu-china_2020_strategic_agenda_en.pdf. Last accessed on 21st May 2014.
127 1st EU-China Innovation Cooperation Dialogue Joint Statement, 2013: http://ec.europa.eu/research/iscp/pdf/policy/china_statement.pdf#view=fit&pagemode=none. Last accessed on 22nd May 2014.

of an Expert Task Force on Innovation Cooperation to identify and promote successful practices in the EU and in China, and to report on the EU-China Joint S&T Steering Committee Meeting and the next Innovation Cooperation Dialogue was agreed. Since then, in March 2014, a Joint Statement was issued by both sides entitled "Deepening the EU-China Comprehensive Strategic Partnership for mutual benefit"[128], which reaffirmed commitment to the aforementioned strategic agenda. At the same time, China issued its own policy paper on the EU "Deepen the China-EU Comprehensive Strategic Partnership for Mutual Benefit and Win-win Cooperation"[129], which mentions areas in which China is interested in STI cooperation.

EU-China cooperation related to research and innovation has followed a two pronged strategy with on the one hand striving for increasing openness and access to each other's funding programmes and on the other specific cooperation in strategic fields and key thematic areas. Currently there are EU-China research & innovation partnerships in the following areas:

- Food, agriculture, biotechnologies (FAB) - Collaboration context agreed through the EU-China flagship initiative for research and innovation in FAB between the EC and CAAS in November 2013[130];
- Sustainable urbanisation - Collaboration context agreed through the research pillar of the EU China Partnership on Urbanisation. In May 2013, the agreed main topics for research and innovation on sustainable urbanisation were: city planning, including urban governance and institutional innovation; green urban mobility and transport; sustainable energy solutions for cities; and Smart Cities[131];
- Aviation and aeronautics – In March 2014, initial workshop discussed potential collaboration topics. It was agreed to conduct a second round of bidding for projects that would be assessed jointly in 2015 and start in 2016[132](Mission of the People's Republic of China to the European Union, 2014). The Ministry of Industry and Information Technology is the main organization overseeing this collaboration on the China side;
- Peaceful uses of nuclear energy – For this topic, the organizations involved are specialised and are based on the PUNE R&D agreement. "Nuclear Security and Safeguards" collaboration takes place between the Chinese Atomic Energy Authority (CAEA) and the Joint Research

128 http://www.eeas.europa.eu/statements/docs/2014/140331_02_en.pdf Last accessed June 2014.
129 http://www.fmprc.gov.cn/mfa_eng/zxxx_662805/t1143406.shtml Last accessed June 2014.
130 http://eeas.europa.eu/delegations/china/documents/eu_china/science_tech_environment/20131108_1_final_report.pdf
131 EU-China workshop "TOWARDS INNOVATIVE JOINT SOLUTIONS FOR COMMON URBANISATION CHALLENGES" Foshan China 30-31 May 2013, EU - CHINA JOINT RECOMMENDATIONS
132 http://www.chinamission.be/eng/kj/t1136195.htm. Last accessed on 23rd May 2014.

Centre (JRC). "Fission Coordinated Actions" are defined between CAEA and the DG Research and Innovation (RTD). MOST and RTD decided on "Fusion Energy Research" collaboration and "Nuclear Safety" collaboration is decided between the National Nuclear Safety Administration (NNSA) of the Chinese Ministry of Environmental Protection, and Joint Research Centre (JRC).

In addition, there is strong collaboration in research and innovation in the following thematic areas:

- Environment/Water – through the China-Europe Water Platform (CEWP) launched in 2012[133]; In March 2014 experts from both sides met to develop draft Work Packages for the Co-lead Partnerships within the CEWP[134];
- Information and communication technologies – the FP7 funded projects OpenChina-ICT[135] and now CHOICE[136] and EU-China FIRE[137] comprise vehicles for supporting the definition and strengthening collaboration in this area. EU-China Expert Groups now exist for collaboration on future internet and Internet of Things (IoT), smart cities and broadband policy;
- Space – the EU-China Space Technology Cooperation Dialogue and the Group of Earth Observation provide the framework for defining areas of collaboration with current cooperation on the Civil Global Navigation Satellite System (GNSS)-GALILEO, and agreement to foster new cooperation areas in satellite navigation science and its application;
- Energy - project twinning has taken place with MoST on concentrated solar panels and innovative batteries, as well as a Joint Call with the Natural Science Foundation of China on biomaterials. An EU-China SME energy conservation and emission reduction research collaboration fund has been established as well as an EU-China Low Carbon Economy Platform[138].

4.3.2 EU-China R&D cooperation programmes

EU-China R&D cooperation in strategic areas, is being implemented via increasing access to each other's funding programmes. The EU's FP7 and now Horizon 2020 are completely open to participation from China including International Incoming/ Outgoing Fellowships, supporting researcher mobility. Previous chapters of this report have also alluded to which Chinese programmes are accessible to EU

133 China-Europe Water Platform, http://cewp.org/. Last accessed May 2014.
134 http://cewp.org/news/co-lead-partnerships-successfully-launched. Last accessed May 2014.
135 OpenChina-ICT project website: http://openchina-ict.eu/. Last accessed May 2014.
136 CHOICE project website: http://euchina-ict.eu/. Last accessed May 2014.
137 EU-China FIRE project website: http://www.euchina-fire.eu/ Last accessed June 2014.
138 http://www.chinalce.eu/ Last accessed June 2014.

researchers. In addition, two programmes have recently been specifically designed to provide specific support to EU-China R&DI cooperation.

The first of these programmes relates to funding from the Chinese side, the **China-EU Science and Technology Cooperation Special Program**[139]. Launched on January 22, 2013 by MOST, it is designed to fund China-EU Science and Technology Cooperative Projects in themes from urbanisation and renewable energy to ICT and health. Projects require at least 2 European partners and funding of up to 3 million RMB (0.35 million Euros) is for the Chinese side only.

To ensure funding for EU researchers, in April 2014, the **EU-CHINA RESEARCH AND INNOVATION PARTNERSHIP (ECRIP)** was launched by the EC offering 4 Million Euros to fund mobility of EU Researchers to China[140] and distributed across five lots of EUR 800 000 each, corresponding to five projects identified under the following strategic thematic areas: Lot 1: Renewable energy, energy efficiency, sustainable energy solutions for cities; Lot 2: Sustainable urban development and urban planning, green urban mobility and transport; Lot 3: Health, public health and welfare policies - life sciences; Lot 4: Information and communication technologies, smart cities; Lot 5: Food, agriculture, bio-technologies and water.

4.3.3 Cooperation between China and other countries

By way of comparison, it was noted that the US is collaborating with China in biotechnology by setting up the Biotechnology Pilot Program. There is long standing cooperation in the area of energy and the environment under the U.S.-China Ten-Year Framework (TYF) on Energy and Environment Cooperation and through the EcoPartnerships programme. Furthermore, the US Department of Energy and CAS have ongoing collaborations in high energy physics, nuclear physics, fusion energy, and basic energy sciences.

Australia is collaborating with China through the Australia-China Council (ACC), which makes recommendations to the Australian Government on strengthening the Australia-China relationship in ways that support Australia's foreign and trade policy interests. The ACC has just released its strategic programme for cooperation for the period 2014-2018[141], which details the proposed focus of its grant

[139] http://news.nost.org.cn/2013/03/china-launches-new-funding-round-for-st-cooperation-with-europe/ Last accessed June 2014.
[140] http://ec.europa.eu/euraxess/index.cfm/links/singleNews/46520
[141] Australia-China Council Strategic Plan 2014–2018, http://www.dfat.gov.au/acc/corporate-information/strategic-plan/

programme and provide seed funds for innovative proposals. The Department of Industry oversees the Australia-China Science and Research Fund[142], which is funding 6 joint research centres in Australia in specific areas of energy, materials, agriculture, and water resources, as well as group missions, symposia, and mobility of young researchers.

There are also many examples of collaboration between China and individual Member States whether by Joint Research Centres, programmes or calls for joint projects. Joint Research Centres can be physical infrastructures or virtual activities. While there are many joint research programmes or funds that address a number of particular strategic areas of collaboration there are also joint research centers or programmes targeting specific individual topics. A collection of 20 randomly selected examples are included below by way of illustration.

China-Italy Design and Innovation Center (CIDIC)
Sino-Swedish Joint Research Center of Photonics (JORCEP)
Sino-UK Geospatial Engineering Centre
UK-China Network of Clean Energy Research
UK-China Stem Cell Partnership Initiative
Sino-French Research Program in Mathematics
Joint Research Institute for Science and Society (Sino-French research)
Sino-French Laboratory in Computer Science, Automation
Sino-French Research Center for Life Sciences and Genomics
Sino-French Institute for Engineering Education & Research
Sino-German Life Science Platform
Sino-German Center for Research Promotion in Beijing
Sino-German Initiative on Marine Sciences
Sino Austria Bio-marker Center
Portugal-China Joint Innovation Centre for Advanced Materials
China - Croatia Ecology International Joint Research Centre
Danish-Chinese Center for the Theory of Interactive Computation
Danish-Chinese Center for Molecular Nano-Electronics
Danish-Chinese Centre of Breast Cancer Research
"Smart Energy in Smart Cities", China – Netherlands Joint Scientific Thematic Research Programme (JSTP) 2014

[142] Australia- China Science and Research Fund: http://www.industry.gov.au/Science/InternationalCollaboration/ACSRF/Pages/default.aspx. Last accessed June 2014.

Institutional collaborations: the main forms of international research/ innovation cooperation

China´s approach to international STI collaboration takes on many forms - from joint academic research to technology transfer and licensing, FDI, mergers and acquisitions – which enable it to be connected to various sources of expertise. China´s willingness "to buy expertise off the shelf" is what differentiates its innovation approach from that of Japan or South Korea[143](Bound, 2013).

Joint Venture is one of the main forms for Chinese companies (SOEs in particular) to promote international research/ innovation cooperation and access foreign technology and funding, as well as management and marketing expertise. This is consistent with the survey conducted by this study which indicated joint ventures and sending personnel abroad as the main forms of international research/ innovation cooperation.

Joint campuses, programmes and research networks are popular forms of academic collaboration. The main benefits to open a joint research centre or lab in China could be to obtain access to data, research facilities, funding, or knowledge. In November 2012 a joint workshop, organised by the by the EU delegation and EU Member State embassies in Beijing was held to exchange views and experiences with joint structures[144].

The EU SME Centre, the IPR China SME Helpdesk, the EU Delegation to China and EURAXESS Links China have recently developed a handbook with guidelines on the issues to consider when setting up and developing a Europe-Chinese joint research structure in China including some of the main challenges that may be faced[145](EU SME Centre, 2013). This publication noted that over 60 joint structures existed between public universities as of the end of 2012.

Sending personnel abroad is also another important form of international research/ innovation cooperation for Chinese public research organisations according to the survey conducted by the current study, besides participating in international collaboration projects and fellowship programmes. In this context, the difficulty of EU researchers in going to China in comparison with Chinese researchers going to the EU was highlighted. The substantial information asymmetries

[143]CHINA'S ABSORPTIVE STATE Research, innovation and the prospects for China-UK collaboration, NESTA, 2013

[144] http://news.nost.org.cn/2013/01/research-report-available-on-joint-research-centres-and-laboratories-in-china/ Last accessed June 2014.

[145] How to establish a Europe-China Joint Research Structure?, November 2013: http://ec.europa.eu/euraxess/data/links/china/docs/Handbook%20How%20to%20Establish%20an%20EU%20China%20Joint%20Research%20Structure.pdf Last accessed June 2014.

regarding the support for EU researchers to go to China and support available for them in Chinese partner institutions were key aspects associated with this.

Several respondents to the survey conducted by this study also said that establishing contacts with research organizations through visits, international conferences and co-authoring were also important forms of cooperation.

Finally, it is important to note that with the increased support available to overseas returnees from universities and research organizations, they are likely to play an increasingly important role in bringing in new scientific and technological information and improving the research and teaching performance in China as well as in promoting international collaboration.

The main function of international cooperation in developing China's STI capabilities

International R&D&I cooperation has opened new opportunities for China, namely to attract international partners to get involved in the development of joint activities, products, service and business models, in particular for Chinese SMEs that can benefit from the resources of large research consortia.

The interviews and survey conducted by the STI China project team also highlighted that international cooperation has attracted foreign technologies and human capital, as well as facilitated China's ability to learn and assimilate the latest knowledge in relevant fields, catching up with the developed countries. This is in particular an important topic, as China strives to develop itself by embracing various technology transfer methods. Moreover, as reported by most respondents, the international influence of foreign firms and international cooperation has upgraded the technological platform of China, and brought new perspectives in the S&T field, thus improving its quality. International cooperation was also seen as helping in the identification of gaps/opportunities for improving STI capabilities. Exchange programmes, and setting up networks (e.g. alumni networks) were pointed out as good ways to encourage and promote continued collaboration with individuals returning from Europe. Similarly, most interviewees stated that the EU can benefit from the knowledge of the EU nationals that have experience in China by promoting the organization of a network of EU citizens that live or have lived and worked in China via such networks, workshops or discussion panels, among others.

5. Framework conditions for STI in China

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5. Framework conditions for STI in China

This chapter provides an overview of the Chinese innovation system and of the consequences for innovative operators in China with each sub-section assessing any relevant policies and programmes related to the topic and commenting on the adequacy of the framework conditions to the development of a truly innovative economy.

This chapter includes:

- Sub-section 5.1 on "Development of firms", which discusses the regulations with respect to the creation and development of firms, including the specific case of non-Chinese firms, in particular SMEs and mid cap companies operating in China;
- Sub-section 5.2 on "Public procurement", which examines the indirect impact of regulations on public procurement on foreign firms;
- Sub-section 5.3 on "The role of the "Investment Catalogue", which specifies conditions fixed for this type of investment and the impact on technological and scientific development in China;
- Sub-section 5.4 on "The patenting and licensing system", which covers the policies and main issues associated with the development and progress of the patenting and licensing system especially with respect to IPR protection and its compatibility with international standards and patent systems;
- Sub-section 5.5 on "The development of Chinese standards", which describes the development of these standards and their impacts for foreign stakeholders participating in RSI activities in China.

5.1. Development of firms

There are five main types of Foreign invested enterprise (FIE) which may be established in China: Wholly foreign-owned enterprises (WFOE), Sino-foreign joint ventures which can either be equity joint ventures (EJV) or cooperative joint ventures (CJV), Foreign-invested companies limited by shares (FICLS), and Foreign-invested partnerships. Most foreign companies establish themselves either a WFOE or an EJV.

Current incentives for foreign investment into China

FIEs with an operating period exceeding 10 years can have tax exemption in the first two years of operation and three years of tax concession at half rates, starting in the third year of operation. These tax breaks start in the first profit-making year.

Many development zones in China, such as Tianjin Economic – Technological Development Area, provide different incentives (including reduced income tax) to foreign service providers and high-tech companies operating in the zone.

Challenges for Foreign SMEs in China

Foreign SMEs in China encounter greater difficulties in dealing with economic, regulatory and market challenges than larger companies. Despite the government's efforts to improve the business environment, the system is still favouring large enterprises. The key challenges for foreign SMEs in the Chinese market are detailed below.

Financing Restrictions

European SMEs in China have limited resources to surpass illiquidity: they do not have access to the same range of financing channels as Chinese companies have.

New restrictions on Representative Offices

New restrictions were issued in January 2010 regarding representative offices of foreign companies, in terms of maximum number of representatives, shorter validity of the Registration Certificate, and at least two years of operations prior to opening the representative office.

The interviews conducted by the STI China project confirm that many newly established foreign companies choose WOFE as their legal form in China rather than representative offices as in the past. This may be justified by the restrictions mentioned above.

Regulatory barriers and Access to Information

Foreign SMEs have limited access to relevant regulatory information, difficulty in understanding the changes in the regulations and do not have the resources and expertise to effectively deal with high volume of administration work. The interviews conducted by the STI China project confirmed that it is difficult for European SMEs to get accurate information on laws and regulations, there are lengthy administrative procedures and it is hard to find a reliable partner. Moreover, there are regional differences regarding the implementation of national policies due to the autonomy of local governments such as the ones located on the east coast side of China where most R&D investment is

made [146](Bound et al, 2013). In general, interviewees felt that Beijing, Shenzhen and Shanghai are stricter with the implementation of rules and thus it is easier for EU SMEs to do business in these regions than in others.

Increasing Tax Burdens

Foreign SMEs do not enjoy any more reduced taxes as before. A single enterprise income tax rate of 25 per cent applies now to both FIEs and purely domestic enterprises. Since 2010, foreign enterprises and FIEs have been required to pay a city construction tax (7% in city areas, 5% in country and township areas and 1% in other areas) and an education surcharge of 3%, from which they had been previously exempted.

Protectionism and compulsory technology transfer

Some Chinese policies such as those concerning Joint Ventures require compulsory technology transfer to Chinese companies if foreign companies wish to operate in the Chinese market. This leads to the risk of Chinese companies becoming their competitors in the world (China vs. the World: Whose Technology Is It?, 2010).

Human resources

The interviews conducted by the STI China project found that there are many limitations for foreign companies to hire people from abroad. The new visa policy also introduces further barriers. Hence, more and more R&D activities have to be carried out by the Chinese staff. Meanwhile, finding and maintaining suitable Chinese employees is also a challenge for foreign companies.

5.2. Public procurement

Due to the fast-growing economy and government policy to increase the procurement volume and scope, public procurement in China has seen an average annual growth rate of 25% over the past seven years [147](2013 White Paper, AmCham China). The European Chamber estimated that China's public procurement market is worth about 20% of China's GDP[148] (EUCCC Position Paper on Public Procurement 2013/2014).

Under the 12th Five-Year Plan, infrastructure projects in areas such as civil aviation, railways, airports, and energy are proposed to expand rapidly. This plan also includes guidelines to standardize

[146] CHINA'S ABSORPTIVE STATE Research, innovation and the prospects for China-UK collaboration, NESTA, 2013
[147] American Business in China, AmCham China, 2013
[148] Public Procurement in China: European Business Experiences Competing for Public Contracts in China, EUCCC Position Paper, 2013

government procurement level and terms for product specification across administrative levels. If successfully implemented, evaluation transparency and accountability should be enhanced.

The MLP describes the role of public procurement in encouraging indigenous innovation and the objective till 2020 (around 40% of total procurements), stimulating demand and investment in R&D. Priority is given to companies which can transfer technology and provide training and other forms of compensation in government procurement activities [149](Tang and Li, 2011). *Circular 618* from 2009, clearly links indigenous innovation to government procurement. To be considered as "indigenous innovation" the product manufacturer must own IP in China, with a trademark belonging to a Chinese company, be registered in China and incorporate a high degree of innovation. However, in 2010 China's government released revised draft provisions, under which most products by foreign companies in China can be certified as indigenous innovation products and be eligible for preference in government procurement.

Challenges for foreign companies

Chinese government policies related to public procurement present several challenges to foreign companies, including difficulties with access, a lack of transparency in the procurement process, and the decentralization of this process.

Access to Public Procurement

The Chinese public procurement market is not easily accessible for foreign companies. FIEs are normally excluded from participating in the Tendering and Bidding Law (BL), including most infrastructure and public work projects. The Government Procurement Law (GPL) does not include the projects offered by public entities and SOEs that are of public interest and/or use public funds. For those that are accessible, Chinese companies seem to be the preferred ones. The third offer that China submitted to the WTO in 2011 still had a limited coverage and contrasts with the reality in which local government procurement is conducted through projects by SOEs. The fact that foreign interviewees consulted in this study want equality with Chinese companies suggests that the situation of discrimination is not entirely resolved despite legislation stating to the contrary.

Also according to opinions gathered through the survey conducted in this study, public procurement in China lacks transparency, as it often happens that the winner is already chosen before the public tender has been announced. Opinion was that local companies and industries benefit from it while

[149] Mini Country Report/P. R. China under Specific Contract for the Integration of INNO Policy TrendChart with ERAWATCH (2011-2012), 2011

foreign companies have difficulty in accessing such opportunities and need to use agencies. Further, European SMEs do not have good access to public procurement information, nor the proper channels to apply for them, thus leading to unfair competition. Barriers were believed to exist for foreign companies especially in the areas of IT, banking and insurance.

Non-transparent drafting of procurement catalogues

Central and local government procurement can only cover goods or services listed in the Central Procurement Catalogue. The catalogue is updated by the State Council at central level and by provincial government at local level. Foreign companies usually are not aware of any public consultations during the drafting of national or local government procurement catalogue[150] (EUCCC Position Paper on Public Procurement 2013/2014).

Decentralization of the tendering and approval process

In China, the majority of public bidding for government procurement is for the ministry or a public entity, and any tender of public interest has to go through public bidding. Most provinces have their own local regulations on government procurement with different requirements to the GPL. The public tendering and approval process is increasingly decentralized. For example, there is no centralized website available with information on new GPL tenders. Thus, companies need to build and maintain a contact network at different levels of government to stay informed about opportunities. It is therefore hard for SMEs, which have less resources than large companies to compete.

5.3. The role of the "investment catalogue"

The first Foreign Investment Catalogue was promulgated in 1995, and is now on its fifth revision. The aim of the catalogue is to categorize foreign investment in China in specific industries as “encouraged”, “restricted” or “prohibited”. If an industry is not referred to in the catalogue, it is considered as “permitted” [151](Keene, 2012).

Foreign investments in “restricted” industries need to meet more complicated and more burdensome application requirements than those “encouraged” or “permitted”, as well as stringent government review. Meanwhile, foreign investments in “encouraged” industries are eligible for investment

[150] Public Procurement in China: European Business Experiences Competing for Public Contracts in China, EUCCC Position Paper, 2013
[151] http://www.allens.com.au/pubs/asia/foasia22feb12.htm, last accessed in November 2013

preferences, and companies can benefit from the less strict government review and the fewer ownership restrictions.

The Catalogue also states the specific forms that investment should take, such as a Sino-foreign equity joint venture. In addition, it also defines the foreign shareholder's maximum stake in the enterprise.

The Investment Catalogue and the five-year plan by the Chinese government allow the foreign companies to know where to concentrate their efforts (for instance, environment, energy and public health), areas in which the Chinese government encourages and allocates more funds. They are thus an indicator of demand.

2012 Newly Revised Foreign Investment Catalogue - Encouraged Category

Aims of the 2012 Amendments to the Catalogue are:

- Gradual opening of China's economy to foreign investment;
- 12th Five Year Plan focuses on the "strategic emerging industries" (please see below the seven industries addressed);
- 12th Five year Plan promotes the development of less developed regions of the country, aiming to overcome the inequalities between eastern and southern cities and the western, central and north eastern cities of China.

The encouraged industries in the 12th Five year Plan are the following: 1) Energy saving and environmental protection; 2) New-generation information technology; 3) Biotechnology; 4) High-end equipment manufacturing; 5) Renewable energy; 6) New materials; 7) Clean energy vehicles.

These and other changes to the encouraged category reflect China's willingness to liberalize some sources of investment capital, assisting the development of small businesses and promote innovation technologies (Herrold et al., 2012).

According to interviews conducted in the current study, further opening of the permitted industries would be desirable – the automotive sector, areas such as new materials, space and new energy were all areas where joint ventures were proposed as a means to transfer technology required by China and allow participation of FIEs in these activities.

Challenges for foreign companies

Generally, foreign investors would invest in any non-prohibited or non-limited industries after they obtain the approval from the Chinese government. However, according to interviews conducted by

the STI China project team, China's investment approval authorities sometimes may favour domestic competitors over foreign investors. Hence, the investment catalogue for foreign firms is still viewed by many foreign firms as a domestic protection mechanism, not facilitating fair competition. The current solution for this is the free trade zone, although even here, many consider that not many changes have occurred.

5.4. Patenting and licensing system

In the following sub-section an overview of the development and progress of the patenting and licensing system especially with respect to IPR protection and its compatibility with international standards and patent systems has been developed.

IPR organization

With the integration in the World Intellectual Property Organization (WIPO) in 1980 and the accession to WTO in 2001, China complied with the requirements of the WTO Trade-Related Aspects of Intellectual Property Rights (TRIPS) Agreement, which addressed IPR and created laws and tools to have a good IPR protection.

The State Intellectual Property Office (SIPO) is the authority that receives and analyses patent applications in China. There are 3 ways of filing a patent: 1) direct filing in China (for foreigners, they must use a local patent agent); 2) file a patent in the foreign country and then file an application in China within 12 months, prioritizing on the first application; 3) file an international patent under the Patent Cooperation Treaty (PCT). This way the patent could be filed in an EU country and the national phase with SIPO should be no later than 30 months after the first application with PCT. It is essential to apply for patent protection in China when there are innovation activities. The evaluation of patent applications takes around three years and is performed by SIPO[152] (Delegation of the EU to China, 2011).

Copyright registration in China is free, easy and is highly recommended. It works in the same way as in Europe, arising automatically upon the creation of copyrightable work. The registration is a proof of ownership evidence, but if the copyright is not registered, it is advisable to keep evidence of the creation and ownership of the copyright. Also, the work has to contain the author's name, date of creation and use of the © symbol. In China, the commissioned party owns the copyright for the work.

[152] IPR in China: Guidance for Researchers, Delegation of the European Union to China, 2011

Policy context

China has made huge progress in recent years with respect to IPR protection. In 2011, a study identified areas still requiring improvement including political measures to pursue enforcement, lack of coordination between government agencies, lack of resources for enforcement, local protectionism and lack of judicial independence (James McGregor, 2011).

To prevent counterfeiting goods, China has established anti-piracy and anti-counterfeiting laws and regulations. Since 2006, there have been criminal penalties for breaking these laws (Brad Herrold, 2012). However, one criticism was that these laws were not sufficiently enforced. Efforts have intensified in recent years in this area through a "Special Campaign". Figures in the **White Paper on IP protection**[153] providing the results of this campaign state that from October to December of 2010, a total of 805 patent cases were settled, 44.16% of the yearly amount. In terms of patent prosecution, China has also joined the Patent Prosecution Highway mechanism, promoting the acceleration of patent prosecution procedures. This will benefit both foreign and domestic companies that want to file patents abroad. Moreover, the Supreme People's Court (SPC) has adopted some US techniques for judicial interpretations of patent infringement.

The 3rd revision of Patent Law, whose regulations for implementation came into force on 1st February, 2011 has brought further improvements at a legal level.

In April 2011, the China National Intellectual Property Strategy Office published "China's Action Plan on Intellectual Property Protection 2011". This action plan intends to amend IP laws and regulations in order to support IPR enforcement. It also refers to the need to strengthen the cooperation between China and international institutions.

In November 2011, at the 22nd Session of the Joint Commission on Commerce and Trade (JCCT), a number of IPR concerns were presented. The IPR Working Group committed to deepen the dialogue about patent quality issues, government benefits regarding the owning and development of IP. In line with China's 2011 JCCT commitments, in November 2011 the State Council issued an internal circular entitled "Notification Regarding Deepening the Work for Removal of Documents Linking Innovation Policies to Government Procurement Policies" repealing national regulations that impose domestic IP requirements for government procurement.

[153] White Paper on IP Protection, SIPO, 2010, http://english.sipo.gov.cn/news/official/201303/t20130326_789188.html. Last accessed on 16th May 2014.

The State Intellectual Property Office (SIPO) formulated and promulgated the 12th Five-Year Plan for IP Talents in order to improve human resources available to tackle IPR issues. SIPO has also introduced a series of partial regulations, such as “patent administrative law enforcement”, “patent examination guidelines”, “patent pledge registration" system, among others, which makes the process more transparent.

Regarding the **National IP Strategy Plan for 2013**[154,155]**,** SIPO has announces that it will:

- Prepare a work plan for intellectual property in China’s Strategic and Emerging Industries;
- Prioritize patent examination for industries such as clean energy;
- Improve copyright reporting, particularly the economic contribution of these industries;
- Increase hearings for IP cases, and experiments combining civil, criminal and administrative IP cases;
- Promote openness in administrative proceedings as well as improve coordination between administrative and criminal enforcement;
- Stimulate software legalization by the government and pre-installation of legal software;
- Continue effort on patent administrative enforcement;
- Conduct preparatory work for China to join the Hague Convention on industrial designs;
- Enhance the protection of geographical indications (GIs), and continue negotiation of the Sino-European agreement on GIs;
- Develop access and benefit sharing rules for genetic resources;
- Enhance IP Management in national science and technology projects;
- Develop new rules and practices for transgenic biotechnology, including new rules on IP protection in this area;
- Foster conditions for development of indigenous IP for overseas students returning to China;
- Continue to advance IP knowledge among students, as well as the IP service professions.

In April 2013, the SIPO Commissioner said that IPR protection in China is a long-term and complex process, but it has been improving, and it needs cooperation with other countries, instead of confrontations. Indeed dialogue between the EU and China on IP issues has taken place since 2003[156]. The EU-China IP Dialogues and related IP Working Group, as well as two previous joint IPR

[154] http://chinaipr.com/2013/03/25/national-ip-strategy-plan-for-2013/
[155] Promotion Plan for the Implementation of the National Intellectual Property Strategy in 2013, SIPO, March 2013, http://english.sipo.gov.cn/news/official/201303/t20130326_789188.html. Last accessed on May 16th 2014.
[156] http://eeas.europa.eu/delegations/china/press_corner/all_news/news/2014/20140116_en.htm

collaborative projects have taken place are demonstration of significant cooperation in this area during these years. Since January 2014 a new joint project will begin between the Office for Harmonization in the Internal Market (OHIM) and the European Patent Office on the EU side and the Department of Treaty and Law of the Ministry of Commerce, on the Chinese side coordinating the participation of more than 15 Chinese IP authorities. Among its proposed activities are EU-China Customs cooperation on IPR, exchanges on legal and administrative IP issues - including best practices, assistance in drafting IP law revisions and implementing regulations - and the compilation and publication of databases on IPR issues.

Opinions on the current situation

The interviewees questioned in this study confirmed the government efforts in this area and considered that these measures have brought positive achievements recognized by the international community. It was generally believed that future measures of improvement are likely to align China's policies more closely with other international ones. Some suggested further improvements could involve simplifying the rules for evidences and procedures before court as well as creating specialized courts. Also, further efforts in regard to transparency were also suggested.

Challenges for foreign companies

Since for Joint Ventures compulsory technology transfer rights are required, it may result in the total sharing of the know-how with the Chinese partner, dealing with the challenges associated with this topic is of high importance. There are challenges with regard to access to information since there are different patent strategies in different regions in China and the central government regulations are constantly changing which makes it difficult for foreign companies to keep themselves updated. Many illegal copies/counterfeit products still exist in China. It is very hard for a foreigner to get an invention patent and the majority of patents are owned by Chinese universities. Moreover, trademark law is not yet finalized. Foreign companies protect their IP by having support from the local embassy or consulate, by a lawsuit or by non-official measures. To lower the risk of IP leakage of licensing in China, foreign companies are adopting different strategies: 1) "modular strategy": using different suppliers to provide different components for a product; 2) "phased implementation" for research collaborations: first agreeing a limited license to test the partner, and then later the additional transfer of technology; 3) Close collaboration: developing a comprehensive IP agreement, identifying the role of each partner. EU research institutions which tend to enter the Chinese market may be willing to transfer their technology to their Chinese partners, although this sometimes results in the loss of

competitiveness and market share in the mid/long term. Considering this, licensing is sometimes preferred rather than ownership transfer.

5.5. The development of Chinese standards

According to the European Committee for Standardization (CEN), standardization "*can be a bridge between research, innovation and the market, which will in turn bring significant economic benefits*". CEN quotes the World Bank view that, one of the most important economic benefits of standards is increased productivity and innovative efficiency[157] (CEN, 2014). Thus standards are relevant to Science Technology and Innovation because they support the innovation process by providing an important basis for developing solutions and are essential for market update. This sub-section seeks to provide an overview of the status of Chinese standards and their development describing the main bodies involved with overseeing development, the main strategies used and their potential impacts, as well as recent developments in collaborative efforts with the EU.

According to the Chinese Standardization Law, Chinese standards are categorized into 4 different groups, namely: National Standards, Sector Standards, Provincial Standards and Enterprise Standards. In 2011, China had around 3000-4000 National Compulsory standards, around 25,000 Voluntary National Standards. Similarly it is estimated that there are between 40,000 and 100,000 Sectorial/ Industry/ Ministerial Standards with perhaps only around 20 % actively used and again around 15% being mandatory. Beyond this, there are perhaps around 20,000 Provincial Standards of which 20-30% are mandatory. Compliance with compulsory National Standards is a pre-condition for placing products and services on the Chinese market. In addition, and unlike in Europe, compliance with such standards is also required for the export of products and services from China[158] (Ernst, 2011).

One of the most recent phases of standards development in China kicked-off in 2002, with a multi-year research project, which was also part of the 10th Five-Year Plan, aiming to provide future recommendations for this area. In 2005, the results of the project were published, and inspired the Chinese government officials to think further on China's standards system. The results suggested that a complete national technical standards regime aligning with international systems should be built to increase Chinese participation in standard-setting activities at both regional and international level, as well as to increase the adoption of Chinese standards by international standards-setting bodies.

[157]http://www.cencenelec.eu/research/Pages/default.aspx: Last accessed on May 10th 2014.
[158]Indigenous Innovation and Globalization – The Challenge for China's Standardization Strategy, Dieter Ernst , 2011

Chinese standard development is based on a top down approach, normally managed by the Chinese players, affecting the R&D system in China. In the EU, there is a "bottom-up" approach, where the market drives the whole process. However both processes mostly compile standards within Working Groups (WGs). In China these are part of various Technical Committees (TCs), which, for National Standards, are supervised by the Standardization Administration of China (SAC), which has the overall coordination of standardization work in China. SAC is administered by the ministerial body General Administration of Quality Supervision, Inspection and Quarantine (AQSIQ). For sectorial standards, the respective ministry supervises the TCs. Another important body is the China National Institute of Standardization that carries out research on standardization. There are also some important sectorial bodies involved in standardisation such as the China Electronics Standardization Institute (CESI) or the China Communications Standards Association (CCSA) (McGregor, 2011).

Some are of the opinion that the Chinese standards system is overly complex and subject to fragmentation due to the number of stakeholders involved or that there is a lack of structured defined concepts[159] (Ernst, 2011). The consequence of these factors means that the standards policy in China does not exclude the participation of foreign companies, but it gives preference to Chinese firms. This limits the ability of foreign firms to help develop the standard technology system.

In its 2008 review of China's Innovation Policy, the OECD pointed out that China's strategy seems to be to set up technical standards as a means to promote indigenous innovation, while also participating in international standards setting, aiming to promote its standards in this context [160] (OECD, 2008). Some have suggested that this creation of national standards to compete with international ones, acts as barrier to market access, forcing foreign firms to adopt Chinese technologies so that they can do business in China [161](Breznitz and Murphree, 2012). Others see China's policy on standardisation as one of the most significant issues that inhibit transfer of technology to China [162](Atkinson, 2012).

Other studies point out that China also faces difficulties in competing against developing countries whose standards require acquisition of expensive IPR, and thus its development of its own standards is a strategy to overcome these difficulties and compete alongside developed countries such as the US by reducing exposure to royalty and at the same time acting as a co-shaper of international

[159] Indigenous Innovation and Globalization – The Challenge for China's Standardization Strategy, Dieter Ernst , 2011
[160] OECD, OECD Reviews of Innovation Policy: China, Framework Conditions for Innovation, (2008)
[161] How China innovates: Run of the Red Queen, CHINA ECONOMIC QUARTERLY, 2010
[162] Assessing China's Efforts to Become an Innovation Society, A Progress Report, Dr. Robert D. Atkinson, May 2012.

standards[163] (Ernst, 2011). Certainly, the intention is to use standards as an enabler of indigenous innovation, which is seen through the integration of policies on standards with those on innovation, IPR protection, and industrial development. However it is thought that the disconnection to security policies could have a disruptive effect on this process.

According to the survey conducted in the context of this study, a number of responders pointed out that Chinese standards are being developed and improving, with the collaboration between the Chinese patenting authorities and the IEEE Standards Organization cited as a proof of this. When asked about the cooperation methods that the interviewees consulted in this study have with international partners in the areas of IPR and standards, some interviewees also stated that China is promoting international cooperation with other countries through bilateral agreements. These agreements reflect the Chinese government's initiative to promote international partnerships. An example of one such agreement may be demonstrated in the newly signed agreement between China and France to strengthen the development of International Standards and facilitate the adoption of commonly agreed standardization documents on March 26, 2014[164] (CNIS, 2014). This agreement commits both sides to jointly develop international standards and adopting mutual standards in the areas of agro-food, railway transport, e-health /silver economy, and in the sustainable development of cities. As a means to overcome barriers for Germany and Chinese companies, Germany and the Standardization Administration of China (SAC) have developed a Germany-China Standards Information Portal (http://cn-e.standards-portal.de/) to provide a source of information for the standards and standards systems of both countries including over 60,000 standards and this is updated monthly.

Cooperation is also evident with major industry. Similarly in December 2013, the British Standards Institution (BSI) signed an agreement with the Standardization Administration of China (SAC), meaning that industry can put forward British and European standards for potential recognition or adoption by China[165](BSI group, 2014).

At EU level, increasing collaboration can also be evidenced. For example the project "China EU Information Technology Standards Research Partnership", was co-funded by the EU under FP7's 'Socio-economic sciences and the Humanities' programme from 2008-2010[166].This project produced

[163] Indigenous Innovation and Globalization – The Challenge for China's Standardization Strategy, Dieter Ernst , 2011
[164] China National Institute of Standardization (CNIS), http://en.cnis.gov.cn/zdxw/201404/t20140410_19169.shtml: Last accessed on 9th May 2014.
[165] http://www.bsigroup.com/Global/our-services/developing-standards/BSI-Standards-Outlook-2014-UK-EN.pdf. Last accessed on 9th May 2014.
[166] http://www.china-eu-standards.org/: Last accessed on 9th May 2014.

a set of policy recommendations for standards development in this field and its policy brief provides some particularly revealing differences in the way that standards are viewed from Europe and from China[167] (China-EU Information Technology Standards Research Partnership, 2011). In both cases standards present barriers for trade, but for different reasons. They highlight increased cooperation as the means to overcome these difficulties, including R&D and Innovation as a contributor to standardization processes.

One recent step in increased collaboration between the EU and China is the establishment of the Europe-China Standardization Information Platform (CESIP). Launched in 2012, it is designed as a practical information tool for strengthening mutual trade and investment flows between Europe and China by increasing the accessibility of standards and related technical regulations[168] (CEN/CENELEC, SAC 2012). It currently has information on standards in 9 sectors: electrical equipment; medical devices; machinery; environmental protection; aerosol containers; packaging; textiles; toys; child care articles including over 4 500 European Standards, 3 000 Chinese National Standards and 16 000 Chinese Industry Sector Standards with information presented in English and Mandarin.

Thus, it can be concluded that although China has some way to go in terms of addressing certain challenges associated with standardisation. It has certainly come a long way in recent years and collaboration in standardization can be an important way to improve market access and conditions for European companies in China and for Chinese companies in Europe, stimulating global competition and thus, with positive consequences for innovation. Interviews conducted by this study were also in agreement with further collaboration on this topic.

[167] China EU Information Technology Standards Research Partnership European Policy Brief, March 2011, ftp://ftp.cordis.europa.eu/pub/fp7/ssh/docs/china-eu-policy-brief_en.pdf: Last accessed on 10th May 2014.
[168] http://www.cencenelec.eu/intcoop/projects/visibility/CESIP/Pages/default.aspx: Last accessed on May 9th 2014.

6. Conclusions and Recommendations

6. Conclusions and Recommendations

This section aims to draw conclusions from the information gathered and activities provided within this study as regard the challenges and opportunities provided by the development of China the short and medium term (5 years) for the EU, thus up to 2020. These conclusions on challenges and opportunities brought about by the development of China seek to provide information to guide the decision making process in the context of an EU (and its Member States) /China STI strategy, in particular the overall strategy described in the EU-China 2020 Strategic Agenda for Cooperation[169] (European Commission, 2013).

In line with the ToR for the study, this chapter includes specific sections on the following:

- Thematic areas of common interest – including challenges and opportunities for EU- China collaboration in specific thematic areas including specific technology fields and/or subfields for which China currently has the strongest position, as well as those in which China has a future interest;
- Challenges and opportunities for EU higher education and research establishments including cooperation strategies and development of working relationships with Chinese actors in the research and higher education sector (joint research labs or other initiatives, mobility of researchers, etc.);
- Challenges and opportunities for industrial stakeholders with respect to future domains of competition with China in which China might become a S&T supplier in the short to medium term. Challenges and opportunities for SMEs brought about by cooperation with STI infrastructure in China and Chinese firms are also addressed;
- Current gaps identified in the understanding of China's STI system development and solutions to improve understanding on China's STI system on an on-going basis beyond the end of this study.

Recommendations mainly addressed to EU and Chinese policy-makers have also been developed, focusing on the ways in which the reality of China can be integrated in STI policy making and support strategy development as well as help maximise the performance of the different EU actors in the way that they interact with the STI system.

[169] EU-China 2020 Strategic Agenda for Cooperation, http://eeas.europa.eu/china/docs/eu-china_2020_strategic_agenda_en.pdf

6.1. Thematic areas of common interest

This sub-section discusses the challenges and opportunities for collaboration associated with specific technology fields or subfields where China has currently a strong position, as well as those in which China has a future interest. It considers the strategic areas of cooperation as defined by the EU-China 2020 Strategic Agenda for Cooperation and the corresponding activities specific thematic activities that support them including the existence of collaborative research structures or programmes and includes recommendations for future collaboration in each area.

According to the DRAGONSTAR project, which is supporting EU-CHINA STI cooperation activities, regarding future innovation drivers "*the quest or resources and the environmental problems (local and global) will continue to be an important driver, and we could safely expect new technologies on alternative materials, new-generation nuclear plants, as well as on renewable energy*." Thus opportunities may continue to be expected in these areas.

Our study found data on R&D investment and research outputs such as patents and publications suggests increasing competition in: ICT; environmental technologies and renewable energy.

EU-China 2020 Strategic Agenda cooperation for STI include: Food, agriculture, biotechnologies (FAB); Sustainable urbanisation; Aviation and aeronautics; and ICT. Thus we have considered the opportunities associated with each area and provide recommendations on ways in which EU-China collaboration might be improved in them.

6.1.1 Food Agriculture and Biotechnology

Opportunities

In terms of the thematic areas for collaboration, with FAB, opportunities for collaboration are foreseen in addressing the challenges of food waste; in Integrated Pest Management and biological control; organic and low input farming systems; water and soil management; animal husbandry; urban agriculture; and biotechnologies, according to the EU-China flagship initiative for research and innovation in FAB, which is defining the strategic direction for collaborative activities in this area. Regarding opportunities to obtain funding for collaborative activities under these themes, it should be noted that the Chinese Academy of Agricultural Sciences (CAAS) has launched the **Chinese Agricultural Science and Technology Innovation Programme (ASTIP)** for 2013-25, which will address

important topics such as breeding, animal disease control and quality standards on agricultural products. International cooperation will be undertaken in the second phase of this programme from 2016-2020. Also, the EU FP7 funded project LinkTADs will provide further opportunities for strengthening cooperation with China in this area.

In addition, there is an increasing focus on the Green Economy by the EU and China, including considerable development in environmental protection laws, stimulating green economy products and technology. This situation is expected to increase opportunities for R&D and Innovation collaboration in this area since environmental technology R&D and Innovation as well as environmental technology possessed by EU organizations is likely to be in greater demand. In terms of opportunities for collaboration related to the area of FAB and environmental technology, it is relevant to note that the China-Europe Water Platform (CEWP), established in 2012 for supporting dialogue and setting the direction of collaborative activities in this area identified that there are opportunities for collaboration on mitigation of water shortage, flooding and impacts of climate change. Opportunities are also thought to exist for EU enterprises in niche markets. The Green Economy is also likely to be the subject of policy support instruments such as R&D funding programmes which will provide opportunities for collaboration. For example, R&D relevant to the Green Economy was the subject of a collaborative call for proposals funded by NSFC China, Agence Nationale de la Recherche (ANR France), Deutsche Forschungsgemeinschaft (DFG Germany), the Economic and Social Research Council (ESRC UK), and the Nederlandse Organisatie voor Wetenschappelijk Onderzoek (NWO Netherlands) in December 2013[170].

Challenges

The EU-China flagship initiative for research and innovation in FAB identified some important challenges that need to be tackled to facilitate collaboration in this area, some of which were also alluded to in interviews conducted in the context of this study.

The first two challenges identified by the FAB initiative include financing collaboration and raising awareness about the opportunities for collaboration among the research community. A number of interviewees consulted during this study also confirmed these challenges, particularly regarding accessing information about reciprocal programmes and their potential benefits. The third issue that has been detected by the FAB initiative, that will need to be overcome in order to stimulate

[170] Europe- China call for collaborative research on The Green Economy and Understanding Population Change. Closing date: 16:00 GMT 3rd December 2013

collaborative research and innovation in this area, relates to market entry barriers for bio-based products.

Further challenges related to environment and water identified by the CEWP include adapting products to the specific needs of the market; protecting IPR; and finding the Chinese organizations interested in partnering with European enterprises for joint projects in China[171](CEWP, 2013).

Finally, although EU is a global leader in biotechnology (accounting for nearly 50% of global patent applications over the whole time period considered in this study), evidence of European IPR concerns remains, acting as a barrier to collaboration.

Recommendations

A key recommendation highlighted by the FAB initiative is to **set up a mechanism in which approval of a project by either side (EU or China) initiates co-funding from the other side**. As far as EU funding is concerned for SMEs, the possibility of using phase 3 of the SME instrument, in particular the equity facility of the 'access to risk finance' instrument, has been suggested as a potential means to encourage dynamic European SMEs to enter the Chinese market with innovative products and solutions that are close to the end-users and markets.

Concerning the **removal of bio-based product market entry barriers**, the FAB initiative recommended measures such as legislation to promote the use of such products and the development of their market, green public procurement, or addressing standards/labelling claims about these products (e.g. bio-degradability, bio-based content, renewable carbon, recyclability, and sustainability).

Interviewees consulted during this study also recommended **strengthening support to structures that can raise awareness of funding opportunities**. This is an area where international collaboration projects such as the EU funded Dragon star can play a role. EU member states along with specific collaboration structures such as the Austria-China Research Center for Environment Protection, the China-UK Sustainable Agriculture Innovation Network, which can also facilitate such activities. In addition, **dialogue between existing initiatives**, e.g. the EU-China Flagship initiative for research and innovation in FAB and China-EU Water Platform, would encourage mutual learning and exchange.

[171] http://cewp.org/wp-content/uploads/2014/03/E1-CEWP-Business-Pillar-Report_EN.pdf. Last accessed on 22nd May 2014.

6.1.2 Sustainable Urbanisation

Opportunities

Thematic areas in which opportunities for collaboration under the topic of sustainable urbanization are foreseen have been identified in the areas of: City planning, including urban governance and institutional innovation Green Urban Mobility and Transport, Sustainable Energy Solutions for Cities, Smart Cities, by the EU China Partnership on Urbanisation, which is setting the strategic direction of collaborative activities in this area.

In the area of sustainable energies, the existence of the EU-China SME energy conservation and emission reduction research collaboration fund represents an opportunity for collaboration and for EU organizations to provide R&D and Innovation services or technology in China. Also, since the area of renewable energy is one of the emerging industries identified for particular policy support in China, policy instruments to increase R&D and Innovation and help bring new technology to the Chinese market will represent opportunities for collaboration and for EU organizations to help supply the demand for new technology and innovative solutions. For example, collaboration opportunities have been seen recently through project twinning with MoST on concentrated solar panels and innovative batteries, as well as a Joint Call with the Natural Science Foundation of China on biomaterials. Opportunities for collaboration in renewable energy, clean coal, smart grids, energy efficiency, green buildings, e-mobility and carbon markets have also been identified by the EU China Low Carbon Economy Platform. Joint EU-China research centres - China-EU Institute for Clean and Renewable Energy-ICARE and Europe-China Clean Energy Centre-EC2 as well as a number of joint centres between EU Member States (e.g. TU Delft joint centres in Water (Nanjing), and Urban Systems & Environment (Guangzhou), the Sino-Finnish Environmental Research Centre – SFERC, or the LIA – Laboratoire franco-chinois sur les énergies renouvelables) also represent established collaborations in this area upon which there is an opportunity to build.

Challenges

Key challenges associated with the area of sustainable urbanisation were raised in the report of an EU-China workshop "Towards Innovative Joint Solutions for Common Urbanisation Challenges", that took place in Foshan China from 30-31st May 2013. The first challenge is related to reciprocal knowledge on urbanisation processes, in view of the widely different approaches to urban planning, as well as historical and cultural differences. Another challenge is the fact that urban transport collaboration requires compatible standards for energy storage, recharging infrastructure and journey

planning. Concerning energy efficiency of buildings, the main barriers include lack of suitable joint business models, different standards and restricted public procurement procedures. Finally, it was noted that interactions with a range of local and regional authorities are required.

Recommendations

A key recommendation associated with the area of sustainable urbanisation identified within the scope of this study is to strengthen dialogue between this area and collaborative activities in related areas such as the EU-China Smart Cities collaboration as well as activities such as the SME energy conservation and emission reduction research collaboration fund and EU-China Low Carbon Economy Platform.

In addition, it is evident, given that the EU-China Partnership on Sustainable Urbanization is still in its early stages that strong efforts will be required to the build networks of relevant actors as well as mechanisms of dialogue between relevant sectors.

In terms of the removal of market entry barriers, the report from the workshop in Foshan also mentions that the use of public procurement and legislation promoting energy efficiency would be helpful to promote collaboration in this area.

6.1.3 Aviation

Opportunities

China's aviation industry has witnessed rapid growth in recent years, transporting around 300 million passengers in 2012. Thus the increasing demand for innovative solutions to support technology issues faced by this sector, represents an opportunity for EU organizations or EU-China collaborative activities to meet the innovation needs of this sector. As far as collaborative activities are concerned, opportunities for collaboration are currently being identified at strategic level through the EU-China Civil Aviation Project (EUCCAP). In March 2014 an initial workshop discussed potential collaboration topics. It was agreed to conduct a second round of bidding for projects that would be assessed jointly in 2015 and start in 2016. Cooperation opportunities have also been identified on the Civil Global Navigation Satellite System (GNSS)-GALILEO and in satellite navigation science, by the EU-China Space Technology Cooperation Dialogue and the Group of Earth Observation.

Challenges

The EU CCC Position Paper 2013/2014 identified market barriers including restrictions in the area of licensing that negatively affect the involvement of foreign companies in this sector.

From data compiled in this study, Chinese R&D expenditures in aeronautics appear to be significantly lower than those of the EU (contributing only 20% of Chinese R&D expenditures for Other Transport Equipment). Thus there may be some imbalance from the perspective of collaboration in this area.

Recommendations

The EU CCC Position Paper 2013/2014 recommends strengthening of dialogue in this area including the establishment of regular strategic-level aviation dialogue between the European Union and China; the resumption of broader platforms for discussion like the EU-China Aviation Summit last held in 2005; and the continuation of activities such as the EU-China Civil Aviation Project (EUCCAP) after it ends in 2014. The report also suggests continuing work to remove market access barriers.

6.1.4 ICT

Opportunities

In terms of thematic areas representing opportunities for EU-China collaboration, it is relevant to mention that the OpenChina-ICT project proposed the IoT, cloud computing, broadband mobile communication, next generation Internet, network and information security, optical communication, smart terminal and smart cities as priority areas of public cooperation between Europe and China in the coming years[172]. The CHOICE project, which follows on from the OpenChina-ICT project, represents an opportunity to build on the previous collaborative activities. Further, the EU-China FIRE project provides an opportunity for future internet collaboration. In addition, EU-China Expert Groups now exist for collaboration on future internet and IoT, smart cities and broadband policy, improving conditions and increasing opportunities for EU-China STI collaboration in this area.

ICT is an area in which China excels not just in R&D, but also in translating knowledge into innovative products. This is demonstrated by the fact that Electrical and optical equipment is one of China's strongest sectors in which production translates into exports. Patent results also show China holding a share of more than 10% of global PCT patenting in Computers, Electronics and Optical Products. Further, research fields such as Engineering, Materials science, and Computer science are among

[172]http://openchina-ict.eu/files/2014/04/Cooperation_plan-06.04.pdf. Last accessed on 22nd May 2014.

China's top five strongest fields. Thus, opportunities to collaborate with China in this area are essential to ensure a strong competitive environment continues to stimulate innovation.

Challenges

Several key challenges associated with cooperation in this area were identified by the OpenChina project and also expressed in interviews conducted within the scope of this study. Besides technical challenges such as the lack of a common technology architecture and interoperability issues and lack of common standards, there are also concerns about market barriers and IPR as well as internet governance, security and differing privacy policies.

Recommendations

Smart city collaboration was recommended by the OpenChina project to establish knowledge exchange platforms and help strengthen the link between cities and enterprises. In addition, the development of joint solutions such as those being developed under the EU-China FIRE project should be extended to other priority areas. Also, links should be built for collaboration in other strategic areas (e.g. ICT for agriculture, ICT for health).

6.2. Higher education and research establishments

The study's conclusions in regard of higher education and research establishments are presented by comparing the opportunities and challenges associated with different cooperation strategies such as:

- Human Capital Movements;
- Establishing Joint Campuses/Research Centres.

6.2.1 Human Capital Movements

Opportunities

Despite the imbalance between the numbers of Chinese researchers conducting research in Europe and when compared to the relatively fewer European researchers wanting to re-locate to China, there are a number of schemes available to support such researchers, which provide opportunities for human capital movements.

On the European side, these opportunities are increasing. For example, in addition to International Outgoing Fellowships for career development (IOF) - Marie Curie Actions, a new scheme has recently

been established to support the strategic areas of cooperation between the EU and China, the previously mentioned, EU-CHINA RESEARCH AND INNOVATION PARTNERSHIP (ECRIP) which will provide 4 Million Euros to fund mobility of EU Researchers to China. In fact quite a number of Chinese programmes are now open to participation from EU researchers.

Opportunities supporting human capital movements on the Chinese side include:

- MoST programmes: Those open to European researchers include the National Basic Research Programme (973 Programme); the National High-Tech Research and Development Programme (863 Programme); the International S&T Cooperation Programme (ISTCP); and the EU-China SME energy conservation and emission reduction research collaboration fund;
- The International (Regional) Cooperation and Exchange Programme as the main NSFC programme open to European researchers;
- The Einstein Professorship Programme; Fellowships for Young International Scientists; the CAS 100 Talent Programme; and the CPCCC 1000 Talent Plan as the main programmes for CAS researchers to collaborate with European researchers ;
- The CHINA/UNESCO - the Great Wall Fellowship; the Chinese Government Scholarship Scheme; and the Distinguished International Students Scholarship as the main CSC programmes open to European researchers.

Chinese funding appears to be particularly focused on attracting returnees - Chinese researchers (including those who now have a foreign nationality) who have been resident abroad. Thus, the opportunities for human capital movement supported by China are increased for this group. Those that are returning from the EU could also represent an opportunity for EU-China, by facilitating access to Chinese programmes, since they will have an established network of contacts in the EU as well as a greater ease in accessing Chinese programmes.

Challenges

According to information from EURAXESS[173] Chinese research institutions can find it a challenge to promoting themselves internationally. Meanwhile, there is also some lack of knowledge about China and of the quality of its research system among European researchers. In addition, the salaries in China

[173] http://ec.europa.eu/euraxess/data/links/china/docs/Mobility_Meeting_Beijing_7December.pdf Last accessed June 2014.

are lower than those in Europe and the high bureaucracy of the Chinese research system makes it difficult to obtain relevant information and visas.

Recommendations

It is important that reciprocity of human capital movements is emphasized to maximise access to contacts within China. Managing the arrangements through which Chinese researchers return from Europe to China is also considered an important method through which the EU can improve its access to Chinese funding programmes, in which it would normally be difficult to participate.

It is clearly in the interest of Chinese laboratories that managed to attract Chinese returnees from the EU to stay in close contact with their previous European colleagues. It is thus recommended, in order to encourage and maintain the cooperation with the returning scholars, that this aspect should be incorporated into existing programmes and financial incentives – to include, for example, in some way requirement to continue the collaboration with their EU counterpart researchers for Chinese researchers that return to China after a period in the EU.

Respondents to the survey and interviews during the course of this study also noted that, in order to encourage continued collaboration with Chinese researchers and students returning from the EU, it would be beneficial to set up a Chinese alumni network - such as the one in Germany – perhaps targeting specific research areas to encourage them in continuing collaborative activities with Europe. EU researchers returning from China could equally be involved in such a network to increase the impact of their experience in China.

6.2.2 Establishing Joint Research Centres

Opportunities

The project has identified opportunities for EU organizations in accessing incentives offered by the Chinese government to R&D centres funded through foreign investment – these include exemptions of customs duties on imported equipment, business and income tax deductions. It also appears easier for foreign entities that have invested in R&D centres in China to apply for joint participation in key S&T programs, such as the 863 and 973 programmes. The project interviews also indicated that permanent sharing of research facilities and infrastructure strongly helps to increase contacts with the Chinese research community, increasing opportunities for collaboration.

Challenges

According to the handbook "How to Establish a Europe-China Joint Research Structure" co-edited by the EU SME Centre, the IPR China SME Helpdesk, the EU Delegation to China and EURAXESS Links China one of the challenges that may be encountered in such an activity include aligning work between Chinese and EU academic systems which are quite different. This mechanism of collaboration requires the allocation of substantially greater levels of investment than other mechanisms of collaboration of a more sporadic nature. There may also need to be some sensitivity in approaching certain specific topics given China's political environment.

Recommendations

Strengthening of EU support for the implementation of Joint Research Structures in China is recommended to help increase EU access to relevant data, research funding, facilities and talents in China. These joint structures have been reported as offering valuable support to collaborative activities from both sides from an educational point of view by students as well as being appreciated by industry. For example, EU companies have mentioned them in connection with facilitating their cooperation with Chinese companies or universities. In particular, they can be used to assist EU companies to commercialize the research results. Continued support to the implementation of such long-term cooperation mechanisms - providing a "legal and administrative cornerstone" for the cooperation between EU-China research institutions – is thus required.

Recommendations from the handbook "How to Establish a Europe-China Joint Research Structure" co-edited by the EU SME Centre, the IPR China SME Helpdesk, the EU Delegation to China and EURAXESS Links China as well as stakeholders interviewed in this study also consider it important to carefully select the Chinese partner and sign a non-disclosure agreement before starting the negotiation, and emphasized EU SME Centre services to support the establishment of research platforms in China.

6.3. Industrial stakeholders

Section 6.3 examines challenges and opportunities for industrial stakeholders including SMEs and makes recommendations for:

- Industry-Research Collaboration;
- Infrastructure for Industry cooperation.

6.3.1 Industry-Research Collaboration

Opportunities

The increase in the amount of foreign-invested R&D centres in China has been identified as creating more opportunities for collaboration. It is believe that this has been assisted by a series of incentives that support the implementation of such centres. These also increase opportunities for EU companies to both access Chinese R&D human resources and develop R&D localization strategies in line with China's specific market demands.

The increasing clustering of SMEs is also enhancing opportunities for industry-research collaboration by providing a platform for sharing and exchanging of knowledge, ideas and resources, thus fostering industrial innovation. These clusters have allowed EU companies, especially SMEs, to better access their relevant Chinese company and researcher counterparts. The clusters have also become a hub for (Chinese and EU) researchers to seek cooperation with industry.

In March 2013 the 12th National People's Congress outlined the strategic document "Further reform of the S&T system and build enterprise-centred innovation system," released by the State Council in 2012. This policy is designed to strengthen "Industry-University-Research" linkages, and foster research and innovation capacity in the business sector. Thus, while the government acknowledges that a substantial gap remains between industry and academia, a number of initiatives are being established to improve the situation, which means that opportunities are likely to increase for industry-research collaboration.

Further, due to the fact that IPR awareness in China is growing, including by Chinese companies, the conditions for collaborative activities are also improving, thus increasing the probability of industry-research interaction.

Challenges

The study has shown that there still remains a large gap between research and industry in China in many sectors. The comments from interviews were that R&D departments of companies in China mainly focus on development rather than research, whilst Chinese research institutes in general lack experience relevant to provide innovative solutions that are useful to industry. For instance, the study analysis shows that whilst there are a growing number of patents being filed in China, many of them are not then being utilized by industry.

The Investment Catalogue, viewed as a domestic protection mechanism, still remains as a challenge.

Recommendations

Stakeholders recommended further support from the EU to create more opportunities for EU and Chinese science and industry to collaborate. In this respect, the EU SME Centre in Beijing is in a unique position to further the involvement of EU SMEs in clusters (including EU/China cluster-to-cluster collaboration), and it is thus recommended that the EU SME Centre implement a specific strategy for this, working alongside the current cluster development programmes that are being implemented by DG Enterprise and Industry as well as being involved in EU-China dialogue working groups involving such structures.

The opening of the investment catalogue is regarded as very important – and it should be a key EU policy objective to reduce the perceived negative of the catalogue in general. Specific sectors in which interviewees believed the EU could push for further opening include new materials and space technology – allowing EU companies to cooperate more effectively with Chinese research institutions and universities, or set up joint ventures with Chinese partners.

More support was requested from stakeholders consulted in this study on the issue of standardization, in particular pro-active communication with the relevant standards authorities in China to obtain an improved understanding of the changing regulations as well as a means to disseminate this information in more centralized way. One that will also allow EU companies to share experiences in a structured manner. The activity of the current EU-China collaboration in this area CESIP could be expanded and more widely promoted through existing industry structures such as the EU SME Centre in Beijing.

6.3.2 Infrastructure for Industry cooperation

Opportunities

Incubators and science parks are seen as playing an increasing role in the promotion of innovation clusters, technology transfer and possible commercialization of research results in China. In particular, they work as a networking, collaboration and infrastructure-sharing platform for innovators. In this sense, they may represent increased the opportunities for EU organizations, by providing improved conditions for STI activities, in particular the commercialization of research results in the Chinese market.

There are also "Technology Transformation Funds" that help to subsidise equipment upgrades for specific purposes, such as energy saving, emission reduction, and the adoption of new generation technologies. These may provide opportunities for funding STI infrastructure in private organizations.

Significant investments in physical infrastructure that can support industry, with very large investments in renewable sources of power, smart grids and rail transport has been identified, representing improved opportunities for conducting STI activities in China. According to the document entitled "Strategies on deepening the reform of the science and technology governance and speeding up the construction of a national innovation system", China aims to build 50 world-class scientific research centres and 100 national engineering centres, which will also provide improved opportunities for STI collaboration.

Challenges

Access to R&D infrastructure in China remains difficult for EU companies, although in part this is helped through the jointly invested R&D centres.

Another challenge is related to the fact that Joint R&D centres with companies are still immature in Chinese universities. Chinese companies can be focused on developing and improving existing products, rather than research and innovation. For example, China is a world leader in second-generation, process and production innovation, but is still weak at novel-product innovation.

Recommendations

One key recommendation to improve infrastructure for industry cooperation is to increase the role of EU SME Centre in Beijing in clustering initiatives being developed in China. This will support liaison with Chinese companies and allow foreign invested companies (particularly SMEs) to better take advantage of specific policy instruments and programmes as well as to gain access to specific infrastructure – including that specified in the Medium and Long Term S&T Development Plan 2006-2020 seeking to encourage indigenous innovation through government procurement of high-tech equipment. Increasing access of industry to funds is also seen as a means to promote research projects with EU and Chinese firms.

6.4. Recommendations for improving the EU's understanding on China's STI

Since up-dating the data related to the indicators can be done more efficiently than collecting it for the first time, it is recommended that the European Commission comes to a structured agreement for a period of a few years to do an up-date of a given basic list of indicators, for which international comparison is possible and to show the trends in time. Concerning publications, the data is always available, that is: it can be retrieved from the Scopus database at any time by anybody, but here again it is less time-consuming when the up-dating is organized in a structured way and at pre-set moments in time (e.g. same month in the year).

Proposals for such structured agreements should be discussed with others who are engaged in data-gathering activities such as the OECD and Eurostat, in order to avoid duplication and in order to agree on the specifics in terms of method and definitions of the indicators and for instance the aggregation level of the fields of publication concerning the bibliometric data.

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