



# ERAWATCH COUNTRY REPORTS 2011: China

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Technology

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***Acknowledgements and further information:***

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## Executive Summary

The People's Republic of China has experienced exceptional growth over the last two decades. By 2011, China has the second largest economy in the world with a gross domestic product (GDP) of €5.3t (RMB47.2t) or €2,429 (RMB21,851) per capita.<sup>1</sup> Home to a fifth of the world's population, China is the most populous country in the world.

China has established science and technology cooperation with the European Union (EU) since the signing of EU-China Science and Technology Agreement in 1998. A multitude of formal science and technology agreements have been instituted between China and Europe at the EU and individual country level that promotes scientific exchange, research collaboration and coordination among national authorities. Chinese researchers are active participants of the EU Framework Programmes.

Since 2005 China has become the second largest spender on R&D globally. In 2010, Gross Domestic Expenditure on R&D (GERD) in China reached €78.5b (RMB706.3b) after more than a decade of double digit growth.<sup>2</sup> In response to the global financial and economic crisis of 2008-2009, the Chinese government's €0.44t (RMB4t) stimulus package placed a strong emphasis on investment in science and technology to induce economic growth. As a result, GERD (in Chinese RMB) rose as much as 26% from 2008 to 2009. From 2006 to 2010, R&D as a percentage of GDP increased from 1.6% to 1.75%, while the economy maintained a growth rate of more than 8% per annum. The government's latest Five Year Plan (2011-2015) specifies a R&D intensity target of beyond 2.2% of GDP by 2015, a stepping stone towards investing 2.5% of GDP on R&D by 2020.

Moving toward the national R&D investment targets requires investment from both the public and business sector. The 12<sup>th</sup> Science and Technology (S&T) Five Year Plan (2011-2015) indicates that government S&T appropriations, which currently account for 23% of national R&D funding, will continue to increase by 20% annually as in the last ten years. There are targets for the business sector as well – the large- and medium-sized enterprises are expected to increase their R&D intensity to beyond 1.75% by 2015. Moving towards a business enterprise-centred national innovation system is prescribed as a long-term strategic goal in the *Medium- and Long-term National Plan for Science and Technology Development (2006-2020)*. Implementation of the plan has instituted a policy mix to promote business investment in R&D through national R&D programmes, tax credits, R&D subsidies and financial market regulations. The main barriers for business R&D investment are recognised as government micro-management in enterprise activities, lack of policy transparency and ineffective intellectual property law enforcement (MOST 2011).

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<sup>1</sup> This report uses the official European Central Bank exchange rate (annual average) for 2011: 1 euro =8.9960 Chinese Yuan. Source: <http://sdw.ecb.europa.eu/browseTable.do?node=2018794&FREQ=A&CURRENCY=CNY&sf1=4&DATASET=0&sf3=4>

<sup>2</sup> Figures in this report are the most recent and authoritative numbers available as of early August 2012.

China has a large S&T sector. It employs 3.5 million S&T personnel and 1.7 million R&D researchers in 2010, second only to the United States. The recent funding increase since 2005 has helped China to expand its higher education institutions (HEIs) and public research organisations (PROs), improve research infrastructures, attract excellent researchers from outside of China, and send more students to be trained overseas in top universities and research institutes.

### Knowledge Triangle

China’s research and innovation policies are top-down; the central government frequently sets goals and objectives for the research system. Investment in research follows a national strategy of building indigenous innovation capabilities and addressing societal challenges, reflected by priorities in energy, environment, agriculture, and healthcare. Innovation policy has seen continuous government support from the central and sub-national government of pushing into the 13 R&D intensive industries defined by the State Council as “emerging strategic industries”. Expanding access to higher education and postgraduate education is the main priority of the state’s education policy, although there are growing concerns about the quality of the higher education system. Other policy areas such as clean energy gain momentum from time-to-time, but are often secondary to concerns about economic growth and industrial development.

	<b>Recent policy changes</b>	<b>Assessment of strengths and weaknesses</b>
Research policy	<p>The 12<sup>th</sup> S&amp;T five year plan establishes a set of new targets of R&amp;D investment and output for the next five years (2011-2015).</p> <p>The State Council initiates a new round of reform that emphasises building indigenous innovation capabilities and transforming the research sector into a business-centred innovation system (State Council 2012).</p> <p>The Chinese Academy of Sciences has launched the <i>Innovation 2020</i> programme</p>	<p><b>Strengths:</b></p> <ul style="list-style-type: none"> <li>Both national and regional governments have kept a rising trend of R&amp;D investment over the last decades.</li> <li>China has successfully attracted hundreds of top overseas Chinese academic and industrial leaders to return back to China.</li> </ul> <p><b>Weaknesses:</b></p> <ul style="list-style-type: none"> <li>The spatial spread of China’s research activities is rather uneven.</li> <li>It is hard to retain these high profile researchers in mainland China.</li> <li>Preferential policies favouring overseas returnees stifle domestic scholars’ research incentives due to huge difference of stipend.</li> <li>China did not meet its R&amp;D intensity target set in the previous five-year plan in 2010.</li> </ul>
Innovation policy	<p>Current national innovation policy emphasises on fostering the creation and growth of the “emerging strategic industries”. Thirteen of such R&amp;D-intensive emerging industries have been identified and given priorities for support, including information technology, biotechnologies, advanced manufacturing, clean energy, new materials, and new energy vehicles (State Council 2010, 2011).</p>	<p><b>Strengths:</b></p> <ul style="list-style-type: none"> <li>More incentives are provided for R&amp;D investment at both public and private sectors.</li> <li>The strategy of Import-&gt;assimilate-&gt;re-innovate strategy has proven to be a successful model for China’s incremental products innovation.</li> </ul> <p><b>Weaknesses:</b></p> <ul style="list-style-type: none"> <li>Intellectual property protection remains weak.</li> <li>New core technologies cannot be procured via the import-&gt;assimilate-&gt;re-innovate strategy.</li> </ul>
Education policy	<p>The National Medium- and Long-term Plan for Education</p>	<p><b>Strengths:</b></p> <ul style="list-style-type: none"> <li>Problem Access to tertiary education</li> </ul>

	Reform and Development (2010-2020) specifies a set of new goals for investment in education (i.e. education expenditure as percentage of GDP to reach 4% in 2012) and output (i.e. enrolment rates in all levels of education institutes).	has been expanded at a very large scale, thanks to government investment and the reform of the education system <ul style="list-style-type: none"> <li>Resources mobilisation is effective in establishing innovation centres and gathering groups of first-class minds from the world.</li> </ul> <b>Weaknesses:</b> <ul style="list-style-type: none"> <li>Picking-the-winner approach increases resource inequality among Chinese elite universities and other universities.</li> <li>Academic dishonesty in China is becoming a serious. There are on-going concerns about the quality of the higher education system (Zhou et al 2010).</li> </ul>
Other policies	The Ministry of Energy issued amended <i>White Paper on China Energy Conditions and Policy</i> in June 2012. In March 2011, the government announced that it would promote a reform to allow children of internal migrants to take university entrance exam at where they live. A few cities have promised implementation of this policy is due to 2014.	The White Paper reaffirms China's commitment in developing clean energy, signalling greater policy efforts in wind and solar power deployment.

#### Assessment of the national policies/measures

Over the last five years, China has strengthened its R&D capabilities through expanding domestic S&T workforce and overseas recruitment of ethnic Chinese researchers. Thanks to the continuous investment from the public sector, research infrastructure is significantly improved and more accessible than a decade ago. The Chinese universities and public research organisations have higher capabilities than ever before to carry out national R&D programmes. As China is moving towards a business enterprise-centred innovation system, the research system has been restructured to establish stronger linkages with the business sector, reflected in the growing importance of National Engineering Research Technology Centres in technology transfers. Increasing budget from the Chinese government in funding international exchange of researchers and students is accelerating knowledge circulation between China and other major knowledge producer countries. China's linkages with the US in the domain of science and technology have been intensified through the establishment of annual US-China Innovation Dialogue, although a similar mechanism is about to be instituted between the EU and China as well.

	Objectives	Main national policy changes over the last year	Assessment of strengths and weaknesses
1	Labour market for researchers	<i>The Medium- and Long-term National Plan for S&amp;T Human Resource Development (2010-2020)</i> emphasises expanding S&T workforce as a share of total employment.	China has successfully recruited hundreds of top Chinese academic and industrial leaders to return to the country from overseas in the last five years. Yet, reliance on attracting researchers from abroad and the preferential policies to overseas returnees stifle domestic scholars' research incentives.

2	Research infrastructures	China's research infrastructure has significantly improved with the implementation of the <i>2004-2010 National S&amp;T Infrastructure and Facility Development Programme</i> . Current policy attention is shifting towards infrastructure sharing and regional integration.	Support is provided to various S&T activities including basic data, national standards, and resource specimens on a more fair and efficient use of existing research infrastructures. Yet, the transparency of scientific data is still a big concern. In addition, given its size of the population, China has a long way to go in terms of fair use of research infrastructure.
3	Strengthening research institutions	The Chinese Academy of Sciences has launched the <i>Innovation 2020</i> programmes, aiming to further improve the general capabilities of the research system, make breakthroughs in a group of key areas of frontier research, and enhance the capabilities of the research system in technology transfer. The programme is built upon the Knowledge Innovation Programme (1998-2010) that successfully transformed CAS.	Through mobilising resources to prestigious universities and public research institutes China has upgraded the scientific renewal and peers competition of Chinese universities. However, Chinese universities are relying on returnees to fill their cutting edge research laboratories. Less evidence points to the conclusion that home-grown capabilities have strengthened.
4	Knowledge transfer	The Law of Promoting Technology Transfer is under revision by the Ministry of Science and Technology. The revised law is expected to make clearer definitions of rights and liabilities in technology transfer transactions.	The National Engineering Research Technology Centres are becoming the main instruments of providing technical services to the business sectors. Formal institutional arrangements (such as technology transfer offices) are lacking in most Chinese universities.
5	International R&D cooperation with EU member states	The 15 <sup>th</sup> China-EU Summit held in Brussels, Belgium on September 2012, instituted an annual bilateral dialogue on research and innovation starting from 2013.	China and EU has long standing science and technology agreements. China's national R&D programmes and the EU Framework Programmes are mutually open.
6	International R&D cooperation with non-EU countries	In 2011, the US and China signed an extension of the U.S.-China Agreement on Cooperation in Science and Technology.  China, Japan, and Korea launched joint research programmes on climate change, energy saving and disaster prevention.	China's FDI policy and open attitude towards studying abroad facilitates knowledge circulation between China and the major developed economies through frequent personnel exchange and business investment.

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## 1 INTRODUCTION

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The main objective of the ERAWATCH International Analytical Country Reports 2011 is to characterise and assess the evolution of the national policy mixes of the 21 countries with which the EU has a Science and Technology Agreement. The reports focus on initiatives comparable to the ERA blocks (labour market for researchers; research infrastructures; strengthening research institutions; knowledge transfer; international cooperation). They include an analysis of national R&D investment targets, the efficiency and effectiveness of national policies and investments in R&D, the articulation between research, education and innovation as well as implementation and governance issues. Particular emphasis is given to international research cooperation in each country.

## 2 PERFORMANCE OF THE NATIONAL RESEARCH AND INNOVATION SYSTEM AND ASSESSMENT OF RECENT POLICY CHANGES

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### 2.1 MAIN POLICY OBJECTIVES / PRIORITIES, SOCIAL AND GLOBAL CHALLENGES

China formulates national objectives of science and technology development through multi-annual plans. According to *The Medium- and Long-term National Plan for Science and Technology Development: 2006–2020* (hereinafter MLP) and *the National Science and Technology Development Plan for the 12<sup>th</sup> Five-Year Period: 2011–2015* (hereinafter the 12th S&T Five Year Plan), the primary goals of current national policies are building an innovative society by 2020 and strengthening indigenous innovation capabilities, particularly R&D capabilities of the business sector.

In 2011, China announced its 12th Five-Year Plan to compete for technological leadership during the next wave of development. This much-anticipated national plan set up specific goals and targets over the next five years (2011–2015) to accelerate China's economic growth pattern via technological innovation. As specified in this national strategic document, enhancing the competitiveness of enterprises and promoting indigenous innovation are the two major aims of Chinese innovation policy in the next five years. At the same time, China's innovation policy priorities have evolved in line with the needs of national economic development. Between mid-2009 and mid-2011, China's national innovation policy priorities shifted to promote S&T and innovation development in selected fields of social needs (renewable energy, ICT, biotechnology etc.) and to enhance innovation capacity through indigenous innovation activities. Among its national innovation policy discussions, open innovation has become an important concern. Business sectors in high-tech domains are highly encouraged by the Chinese government to "go abroad": to carry out collaborative research, to merge and acquire overseas high-tech enterprises, and to establish overseas R&D bases to drive China's technology and service export.

Societal challenges are taken into account in the MLP. Challenges in environment, energy, agriculture, employment and indigenous innovation capabilities are among the plan's top concerns. The MLP specifies a list of national priorities for research and innovation breakthroughs, including biotechnologies, information technology, new materials, advanced manufacturing, renewable energy, marine science, laser technology, and aerospace technologies (State Council, 2006).

### 2.2 STRUCTURE OF THE NATIONAL RESEARCH AND INNOVATION SYSTEM AND ITS GOVERNANCE

The Chinese economy maintained a strong growth over 2011 with a growth rate of 9.2%. The market expects such growth momentum, largely driven by the post-financial crisis stimulus package, will slow down next year. Nevertheless, China's GDP reached €5.25t (RMB47.2t), and it is the world's second largest economy.

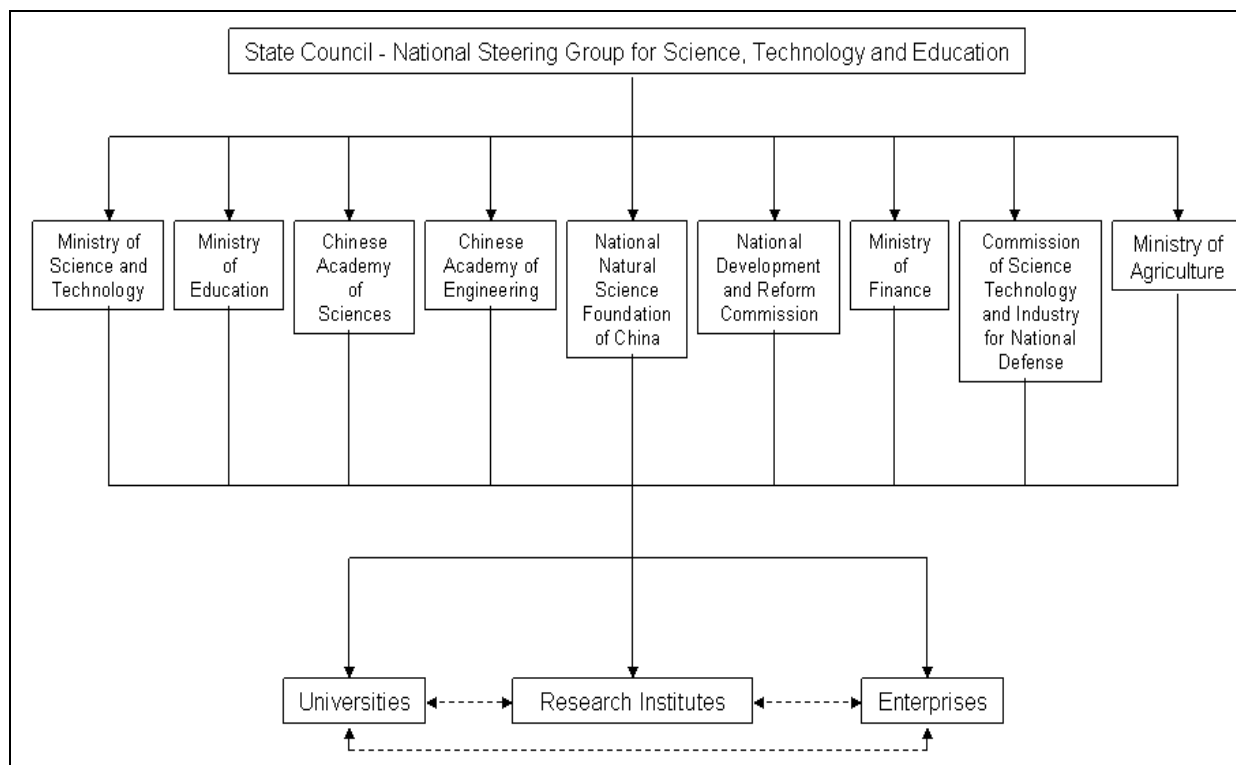
Since 2005, China is the world's second largest spender on R&D, with gross domestic expenditure on R&D (GERD) of €78.5b (RMB706b) in 2010. The size of the Chinese R&D sector is large and continues to increase. R&D intensity (GERD as percentage of GDP) increased from 1.6% to 1.75% during the 2006-2010 period. The business sector remains the biggest contributor to R&D funding, accounting for 72% of the GERD. The government provides about 23% of the R&D funding. In terms of R&D performers, research institutes and universities were the main users (82%) of government funds, while around 14% of government funds went to the business sector.

### **Main actors and institutions in research governance**

The Chinese research system is highly centralised, tightly organised and controlled by the central government in Beijing. The system is composed of three layers in an administrative hierarchical order: the top decision-making body, the policy formulation and implementation agencies, and R&D performers (i.e. universities, research institutes, and business enterprises) (Figure 1). The Chinese research governance structure has a record of being effective and stable in the implementation of national research and innovation strategies. Decisions related to S&T activities are made in the centre, and then go through the agencies and organisations in a hierarchical order.

The National Steering Committee for S&T and Education in the State Council is the highest decision-making body in the research system. It is in charge of strategic goal-setting, medium- and long-term planning, and occasionally, initiating reforms of the research system. On the policy layer, the Ministry of Science and Technology (MOST) is the main government body that formulate S&T policy, make short-term planning (i.e. five year plans), and fund national R&D programmes. S&T policy implementation is carried out by MOST's regional and local branches. Being the economic and industry policy maker, the National Development and Reform Commission is increasingly involved in innovation policies, particularly those related the corporate sector since the national strategy of "indigenous innovation" in 2006. Certain sectoral innovation policies are made in the Ministry of Agriculture, Ministry of Defence, Ministry of Energy, and Ministry of Industry and Information and Technology.

In terms of research funding, the National Natural Science Foundation of China is a major player in addition to MOST. Within the public research system, the Chinese Academy of Sciences (CAS) is the leading institute. CAS also plays a leading role in S&T policy advice and the regulation of public research organisations.

**Figure 1: Overview of China's research system governance structure**

Source: ERAWATCH China Country Fiche

### The institutional role of regions in research governance

Regional governments (provinces, municipalities) in China are granted a high degree of autonomy for regulating and managing the local economy and society. The 1978 economic reform and subsequent arrangements ensured that the regional governments have sufficient capabilities and incentives to promote local economies. The motivation of economic development has been translated into the active roles of regional governments in making research policies and organising local R&D activities.

From Beijing to more local levels, China's national research governance system is characterised by top-down synchronisation. At each level of regional government, a specific branch or personnel is earmarked for science and technology development. Ministries at the national government level have traditionally played the role of policy designers and evaluators, while subordinate agencies have focused on policy implementation. Sub-national actors contribute more than half of the total government S&T appropriation (China S&T Yearbook 2011).

The distribution of research funding in China is concentrated in the east region along the coastal line. The eastern region performs more than two thirds of China's research activities. The provinces and metropolitans with the largest shares of research activities are Jiangsu (12.0%), Beijing (11.6%), Guangdong (11.4%) and Shandong (9.5%). Beijing and Shanghai are the country's most knowledge intensive economies, measured by the ratio of R&D to GDP. Business expenditures on R&D are most prevalent in Shandong, Zhejiang, Guangdong, and Fujian, where funds from the business sector comprise nearly 90% of total R&D expenditures. All of the four locations benefit from a robust private sector and strong entrepreneurship.

## Main research performer groups

The business sector is the largest R&D performer since the late 1990s. In 2010, the business sector conducted 73% of all R&D. Of all industrial R&D, 77% were carried out in large- and medium-sized enterprises. Public research organisations performed 23% of R&D in China, but they used over 60% of government funding in R&D. Higher education institutions performed 8% of the R&D. Over the last five years, R&D performed by each of the business sector, public research organisation and higher education institutes was increasing more than 15% annually.

Public research institutions (PRIs) were the leading R&D performer before being surpassed by enterprises. But they remain the major actors of government funded R&D projects. There are three types of PRIs in China. The most important type includes PRIs that are part of the Chinese Academy of Sciences (CAS), the main research organisation in China. The 97 research institutes managed by CAS are primarily focusing on basic research. A second type includes PRIs affiliated with ministries. There have been hundreds of PRI under different industrial ministries, with a focus on applied and developmental tasks related to the theme of their own ministries. A third type is composed of PRIs at the regional level. They often carry out R&D relevant to the needs of their regions.

Chinese universities carry out around 10% of national R&D over the 2000s. While elite universities like Tsinghua University and Beijing University were traditional research centres, most Chinese universities have a fairly recent history of conducting research activities. In China's three tier system that classified universities into key universities, regular universities, and two- or three-year colleges, R&D is mainly carried out by top tier Chinese universities. By the end of 2010, China had 2,358 universities / higher education institutes (HEIs), among which, 1,354 universities, or 58.7% of total, were engaged in R&D activities.

## 2.3 RESOURCE MOBILISATION

### 2.3.1 Financial resource provision for research activities (national and regional mechanisms)

National R&D investment targets are set through multi-annual plans in China. The current targets are specified in two planning documents, *The Medium- and Long-term National Plan for Science and Technology Development 2006-2020* (or MLP) and *The National S&T Development Plan for the 12<sup>th</sup> Five-Year Period: 2011-2015* (or 12th S&T Five Year Plan). The MLP is the long-term strategic plan. It sets the goal of transforming China into an innovative society by 2020. This goal is measured by four R&D targets: R&D as percentage of GDP to be beyond the 2.5% mark, advances in S&T contributing to at least 60% of economic growth, dependence on foreign technologies reduced to less than 30%, and China being ranked among the global top five countries in terms of patent and scientific publication citations. The MLP concerns societal challenges in environment, energy, agriculture, employment and indigenous innovation capabilities. Accordingly, the plan prioritises R&D

investments in over 60 S&T fields covering energy, natural resource extraction and conservation, environment, agriculture, manufacturing, transportation, information technologies, healthcare, urban development and public security.

The strategies described in MLP are carried out through three five-year plans. Over the last five year plan period (2006 – 2010), China has increased R&D investment from 1.6% to 1.75% of GDP. However, it did not meet the 2% investment goal set in the 11<sup>th</sup> S&T Plan. Although this setback is formally recognised by the central government, it did not result in adjustment or consolidation.<sup>3</sup> Under the current 12th S&T Five Year Plan, the target for R&D investment is set to 2.2% of GDP by 2015. Other targets specified in the 12th S&T Five Year Plan include S&T development contributing to 55% of economic growth and the ranking of national innovation capabilities moving up to global top 18.

Public investment in R&D plays a significant role in reaching the national R&D targets. The government S&T appropriations increased by 20% annually over the last five years. In 2010, the government invested €46b (RMB411b), or 4.58% of the total budget in S&T development. Sub-national governments contribute about a half of the total government investment in R&D. In 2010, five regional governments (Beijing, Shanghai, Jiangsu, Sichuan, and Shaanxi) spent more than €111m (RMB1b) on R&D (China S&T Yearbook 2011). The municipal government of Beijing invested as much as €522m (RMB4.7b) in R&D, as the city hosts a large number of China's leading universities and public research organisations.

The main funding instruments are the national R&D programmes. [\*National Basic Research Programme\*](#) (“973 Programme”) and [\*National High-Tech Research and Development Programme\*](#) (“863 Programme”) are the major national R&D programmes. Each of the programmes has a distinctive emphasis, i.e. basic science, applied science and industrial technology, and typically the funding recipients are mutually exclusive. For prioritised areas in MLP, China also established mission-oriented National S&T Mega Projects. Currently there are thirteen active mega projects, supporting R&D in technologies such as general purpose computer chip, wireless communication, high-precision machine tools, nuclear power, and HIV/AIDS treatment. The Mega Projects operate on their own budgets as well as providing an umbrella scheme pooling funds from other national programmes.

Funding mechanisms for national R&D programmes are mostly competitive rather than institutional. Many of the competitive programmes (i.e. the Mega Projects), require a local match from the applicant (business enterprise or public research organisation) and the sub-national government. But there are special schemes of block funding for targeted institutes or researchers. For example, the researchers recruited through the 111 Plan receive a special research grant for discretionary use (see Section 4.6.1). The 985 Programme also provided block funding to a group of elite higher education institutions with the mission to become world-class universities.

China did not adopt a tax credit approach to spur R&D until recently. Effective from January 2008, the amended Enterprise Income Tax Law offers high-tech and new-

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<sup>3</sup> See the 2011 Government Work Report delivered by Premier WEN Jiabao in March 2011 (Chinese) (Accessed on October 16, 2012, at [http://www.china.com.cn/policy/txt/2011-03/16/content\\_22150608.htm](http://www.china.com.cn/policy/txt/2011-03/16/content_22150608.htm))



tech enterprises a reduced corporate income tax rate (which is 15% instead of 25% for non-high-tech firms) and a tax break of “2-year tax exemption and 3-year 50% deduction” if located in the prescribed areas (i.e. Science Parks). In addition, indirect tax incentives are offered, such as business tax exemption and duty-free import of equipment and spare parts. The more traditional instrument is subsidies. Industrial ministries and sub-national governments often offer special “Technology Transformation Funds” to targeted firms. These funds subsidise the costs of equipment upgrading and new processes for specific purposes, such as energy saving, emission reduction, and the adoption of new generation technologies. The availability and size of the fund, however, vary significantly by sector and region. The Ministry of Industry and Information Technology (MIIT) had proposed a €1.67b (RMB15b) plan to subsidise technology transformation in high-tech firms since 2008. The plan, however, is still in policy channel. In addition, domestic business enterprises are qualified to apply for project-based funding in national R&D programmes.

There is no national mechanism to promote collaborative funding, but it does occur in selected programmes such as the *Spark programme*, which promotes the application of science and technology in agriculture and rural development. The programme explicitly requires the partnership between the applicant, typically a public research organisation, and a business enterprise located in the rural area. The Natural Sciences Foundation of China has nine joint fund programmes in collaboration with industrial ministries and sub-national governments.

No recent policy changes are adversely affecting the funding of research. As indicated in the 12th S&T Five Year Plan, the government S&T appropriation will maintain a 20% annual increase in the next five years. In September 2012, the State Council issued *Guidance on Enterprise Technology Transformation*. Although no specific budget specified in the guidance, it is likely a go signal for MIIT’s €1.67b (RMB15b) subsidy plan. According to Xinhua (China’s official news agency), MIIT estimates the plan will induce more than €33b (RMB300b) business expenditure on R&D.<sup>4</sup> Additionally, the completion of the *National S&T Infrastructure and Facility Development Programme (2004-2010)* implies that a large scale spending on research infrastructure seen in the last decade is not likely to occur soon.

China does not have a long-term or comprehensive national strategy to build mutual trust between science and society. However, certain agencies are concerned about fostering science in the society. The National Natural Science Foundation of China’s Young Scientist Fund provides an educational component in its programme.

The growing awareness of grand challenges is reflected in MLP and the 12th S&T Five Year Plan. The 12th S&T Five Year Plan identified three main societal challenges, which are energy & environmental constraints, aging population, and unbalanced & unsustainable development pattern. The plan states that these areas demand for technological innovations, and signals for increasing funding priorities in the national agencies.

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<sup>4</sup> Xinhua News Agency (2008). Enterprise Technology Transformation is an effective stimulation to the economy (Chinese). (accessed on October 20, 2012 at [http://news.xinhuanet.com/video/2008-12/12/content\\_10493891.htm](http://news.xinhuanet.com/video/2008-12/12/content_10493891.htm))



### 2.3.2 Providing qualified human resources

China has a unified educational system for human resource development for research. Through the National College Admission Exams, Chinese universities and colleges admit high school graduates directly into disciplines and majors which typically provide four-year training in one specific area, i.e. math, physics, chemistry, engineering and the like. In this system, the universities decide the number of students admitted in a given discipline, and adjust according to national policy and market demands. Postgraduate programmes are offered at the research universities and some publication research organisations, i.e. the Chinese Academy of Science. Admission into postgraduate programmes, i.e. Master's and doctoral programmes, are organised through national exams as well, although graduate schools have much higher freedom in structuring the exams and selecting the students. In the Chinese higher education system, it is usually more difficult to be admitted into a programme than to graduate.

One advantage of the Chinese education system is providing a large labour force in science and technology. The Ministry of Science and Technology estimates that China has 3.5 million S&T personnel and 1.7 million R&D researchers (China S&T Yearbook 2011). The size of China's R&D labour force is second only to the US. The *National Medium- and Long-Term Plan for Human Resource Development (2010-2020)* estimates that the number of R&D personnel per thousand workers is around 2.45. However, there are no comparable statistics of human resources in science and technology (HRST) as a share of the economically active population in the age group 25–64. None of the major source of information (Chinese national statistics, OECD, UNESCO, etc.) has indicated plans to provide such data either.

Enrolment in science, math and engineering programmes are traditionally strong in China. Currently, there are about 1.2 million students enrolled in sciences programmes (including math) and 8 million in engineering programmes. In 2010, more than 270,000 sciences (including math) and 2,120,000 engineering students graduated from Chinese universities (China S&T Yearbook, 2011). Engineering is the largest area of study in terms of the number of students, accounting for 36.8% of total graduates and 36.0% of total enrolment. According to the 2012 Chinese College Graduates Employment Annual Report, the demand for engineering students is strongest among all occupations. The matching between education supply and market demands is steadily improving (MyCOS, 2012).

Formal programmes in innovation and entrepreneurial education have not been seriously considered until recently. In May 2010, the Ministry of Education issued a policy document, *Promoting Innovation and Entrepreneurship Education in HEIs*. This document encourages universities to create courses and curriculums on creativity, innovation and entrepreneurship. Some of these courses and textbooks are available to colleges and universities but they are of mixed quality (MyCOS, 2012).

### 2.3.3 Evolution towards the national R&D&I targets

The *Medium- and Long-term National Plan for S&T Development (MLP)* had set the goal of building a business enterprise-centred innovation system in China by 2020. Accordingly, R&D in the business sector is concerned in the last two S&T five year plans (the 11<sup>th</sup> and the 12<sup>th</sup> plan). For the 12<sup>th</sup> five year plan period (2011-2015), the

current investment target for large- and medium-sized enterprises is to increase R&D intensity to beyond 1.75% by 2015. Part of the implementation of the MLP has also been formulated into the policies of fostering the formation and growth of the “Emerging Strategic Industries”. The State Council outlined thirteen of such R&D-intensive emerging industries receiving priorities for government support, including information technology, biotechnologies, advanced manufacturing, alternative energy, new materials, and new energy vehicles (State Council 2010).

China's Business Enterprise Research and Development (BERD) expenditures have grown by 140% from 2006 to 2010, reaching €56b (RMB506b). This growth rate is impressive. Nevertheless, business R&D activities in China are still in a nascent stage. R&D expenditure as a percentage to Gross Industrial Output Value in officially-defined high-tech industries<sup>5</sup> is merely 1.48, much lower than leading countries such as the US (16.89), Japan (10.64) and Germany (6.87) (China High-technology Industry Yearbook 2011). In addition, only about 28% of large and medium-sized enterprises (LMEs) carry out R&D activities. They employ 1.37 million R&D personnel but spend less than one per cent of revenue on R&D.

China's R&D and innovation strategy are carried out in a top-down manner. Current policies to foster public and private R&D investment is prescribed in the MLP and the ministries' implementation plans (i.e. five year plans). According to the MLP, strategies for national fiscal and financial policies can be described in the following five aspects:

- **Stimulating greater R&D investment in R&D performing firms** through tax credits that are given not only to business R&D expenditure but also spending on upgrading equipment. R&D equipment is allowed for accelerated depreciation and duty-free importation. Priorities in foreign currency exchange and finance scheme are given to enterprises setting up overseas research facilities.
- **Promoting the establishment of new indigenous R&D performing firms** by facilitating stock market listing of high-tech entrepreneurial firms. The Growth Enterprise Market, a NASDAQ-style board for small- and medium-sized, high-growth firms was launched at Shenzhen Stock Exchange in 2009. Corporate income tax exemption is given to qualified small- and medium-sized high-tech firms.
- **Stimulating firms that do not perform R&D yet** through increasing the amount of pre-tax deductions for R&D expenditures. The Innovation Fund for Small Technology-based Firms (which provides grants to R&D projects in small high-tech firms) has its budget tripled since 2006.
- **Increasing extramural R&D carried out in cooperation with the public sector** through encouraging industry-academia-PRO cooperation in technology import, assimilations and re-innovation. The National S&T Mega Projects give priorities in joint applications by business enterprises, public research organisations and higher education institutes. Access to public research platforms (e.g. National Engineering Technology Research Centres) is encouraged.

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<sup>5</sup> The officially defined high-tech industries include aircraft and space craft, pharmaceuticals, computing machinery, communication equipment, and medical, precision and optical instruments (China High-tech Industry Yearbook 2011).

- **Increasing R&D in the public sector** via increasing funding to major national R&D programmes, i.e. 863 and 973. A local match from sub-national government is increasingly encouraged as well.

Strategies to **attract R&D-performing firms from abroad** are not defined in recent national policy documents. This might be due to the national strategies of “indigenous innovation”. Yet, sub-national governments frequently offer site location services and tax credits to attract foreign high-tech firms.

The Chinese government is an enthusiastic supporter of innovation and industrial policy. The Ministry of Science and Technology has benefited from successful experiences in the so-called policy guidance programmes, i.e. the Spark Programme and the Torch Programme that fostered local and business investment. The Spark Programme provides support for the application of science and technology in rural development, and the Torch Programme coordinates the construction of Science Parks (see Section 3.4.2). The Ministry of Industry and Information Technology (MIIT) is also a traditional supporter of state industrial policy. In a recent proposal, MIIT estimates a public subsidy of €1.67b (RMB15b) to business R&D will induce more than €33b (RMB300b) investment by firms<sup>6</sup>. In addition, sub-national governments play a profound role in carrying out industrial policies, and the capabilities of the provincial or municipal governments often have determinant effects on the development of a particular sector (Breznitz and Murphree 2011).

As indicated in MLP, the Chinese government seeks to encourage ingenious innovation through government procurement of high-tech equipment and products with domestically owned IPs. The MLP explicitly states that indigenous innovation products have priorities in public procurement and should be given a price advantage; furthermore, no less than 60% of government expenditures on technology and equipment purchase should be spent on products from domestic firms. Sub-national governments generally implement this policy through rolling out Indigenous Innovation Product Catalogue on an annual or biennial basis. Products listed on the catalogue enjoy higher priorities in receiving government contracts.

China is generally perceived as a lack of framework support for innovation as well as ineffective IP protection. Sub-national governments have substantial discretions in the regulation of business subsidy, labour market mobility and environmental compliance. Both the MLP and 12th S&T Five Year Plan have emphasised plans to improve the innovation environment. These measures include reducing government micro-management in enterprise activities, improving policy transparency, and enhancing intellectual property law enforcement.

## 2.4 KNOWLEDGE DEMAND

Demand for knowledge is proxied by the expenditure of firms on R&D by sector. According to the statistics from MOST, the largest manufacturing sectors based on R&D expenditures are computer/electronic products (17%), transportation equipment (14%), electrical machinery (11%) and metal processing (10%). The

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<sup>6</sup> Xinhua News Agency (2008). Enterprise Technology Transformation is an effective stimulation to the economy (Chinese). (accessed on October 20, 2012 at [http://news.xinhuanet.com/video/2008-12/12/content\\_10493891.htm](http://news.xinhuanet.com/video/2008-12/12/content_10493891.htm))

sectoral structure of R&D is consistent with the structure of national economy. Manufacturing is the dominant sector, accounting for 46% of China's GDP. The service sector accounts for 43% of the GDP, but the Chinese national agencies do not collect R&D statistics from non-manufacturing sector. The sectoral structure of R&D expenditure is also consistent to the pattern of innovation in China. The information and communication technology sector is the largest high-tech export segment, and the primary driver for innovation (Breznitz and Murphree 2011).

In terms of types of firm ownership, the domestic firms conduct the majority of business R&D, making them the main sources of knowledge demand. Domestic firms contributed up to 74% of total business R&D expenditure. The remainder comes from foreign invested firms (17%) as well as firms with funds from Hong Kong, Macau, and Taiwan (9%).

## 2.5 KNOWLEDGE PRODUCTION

### 2.5.1 Quality and excellence of knowledge production

China has a large and increasingly effective research system. This system employs 3.5 million S&T personnel and 1.7 million R&D researchers, second only to the US. It is supported by €46b (RMB411b) in government science and technology appropriation in 2010. There are over 7800 R&D units in the country's 2300 higher education institutes employing 0.6 million researchers. The Chinese Academy of Sciences is the leading public research organisation, which conducts basic and applied researches through its 97 institutes. In terms of output, China is now one of the largest contributors to knowledge creation globally. The number of Chinese papers indexed in the Web of Science database increased at an average annual growth rate of 29.3% between 2000 and 2009. In EI Engineering Village, a more engineering-oriented database, the number of Chinese papers also increased from 18,600 to 93,000 during the same period, representing an average annual growth rate of 40%. China authored SCI papers have their impact factor steadily increased from 1.58 in 1995-1999 to 3.80 in 2005-2009 (China S&T Yearbook, 2011). In terms of patenting, Chinese domestic patent applications grew from 134,000 in 1999 to 1,109,428 in 2011 filed in the State Intellectual Patent Office of China (China S&T Yearbook 2011).

The *Medium- and Long-term National Plan for S&T Development* (MLP) set the goal for China to be ranked among the global top five countries in terms of patent and scientific publication citations by 2020.

### 2.5.2 Policy aiming at improving the quality and excellence of knowledge production

Adopting a peer review system and following principles of best international practice are on-going policy concerns in improving the quality and excellence of knowledge production in China. Over the last decade, peer review has been widely adopted by top academic journals published in Chinese. In national R&D programmes, research funding proposals are subjective to external review of peer scientists, funded projects must submit reports of progress, and hold expert review meetings by the end of the

project. Higher education institutes and public research organisations are subjective to monitoring and evaluations from the ministries under which the institute is organised. Typically evaluations are held on multi-annual basis. Evaluation criteria include international rankings of higher education institutes as well as output indicators such as the number of SCI indexed publications, citations and impact factors.

A recent international evaluation of the National Natural Science Foundation of China (NSFC) discovered that peer review, output-indicator-based evaluation, and other internationally recognised practices are adopted in China's top performing research projects. The report identifies the current issues in quality assurance are insufficient staffing in the funding agencies comparing to explosive growth in research projects, limited confidentiality protection of the review process, and the need to include early-career scientists with strong research reputations as well as international researchers in participating the review boards (Zaire et al 2011).

## 2.6 KNOWLEDGE CIRCULATION

### 2.6.1 Knowledge circulation between the universities, PROs and business sectors

To encourage R&D activities and promote technology transfer and commercialisation, high-tech zones and incubators have been established in many parts of China. By 2006, 53 high-tech zones hosted more than 90% of high-tech firms and incubators. These firms enjoy preferential tax treatment for conducting R&D activities. Meanwhile, partially due to the pressure of public budget cutting, Chinese universities and research institutes have created spin-off companies, through which they commercialise technology and R&D products developed in their research labs. Spin-offs not only provide a channel for technology spill-over, but also help to stimulate further R&D by generating revenue. By 2004, more than 2,300 university spin-offs had been created in China, with total revenue of €8b. These spin-off companies only account for a small proportion of China's total industry, but they create advanced technologies and are valuable in the development of the high-tech industries. Additionally, within the context of knowledge triangle, spin-off managers have easy access to job-training and life-long learning opportunities given their geographic and social proximity with Chinese universities and public research institutes

Knowledge circulation between the universities, PROs, and business sectors in China occurs through university-industry technology transfers and national programmes for technology diffusion. Knowledge transfers from universities to industry typically involve contracts of technology services, patent licensing and sales, and university-affiliated enterprises (Wu 2010, Wu and Zhou 2011). The Law of Promoting Technology Transfer issued in 1996 supports the rewarding of discoveries of new, commercially useful knowledge, and allows research contracts and patent licensing. Establishment of university-affiliated enterprises is supported through university science parks in which sub-national governments provide free land allocation, infrastructure and facility support. Some cities also collaborate with universities in setting up business incubators, which provide short-term funding and business



support to university faculty and graduates. However, research commercialisation and technology transfer have limited scales. The size of markets for research contracts and patent licensing is only about €0.22b (RMB2b) and €50m (RMB450m), respectively. University-affiliated enterprise sector, though limited in size, has given birth to many of China's leading high-tech firms, including Lenovo (affiliated with the Chinese Academy of Sciences), Founder Group (affiliated with Peking University), and Tongfang (affiliated with Tsinghua University).

The second mechanism of knowledge circulation is national programmes with a mission of technology diffusion. The National Engineering Technology Research Centres (ETRC) is currently the main national scheme that provides technical services to the industry. Over the last five years, ETRCs gain greater policy importance due to the national strategy of building an enterprise-centred innovation system. There are over 250 operating ETRCs, with half of them hosted in universities and public research organisations and the other half hosted in business enterprises. Government funding contributes €0.4b (RMB3.6b), or a third of all investment in ETRCs by 2010. ETRCs provide contracting technical services in the forms of product prototyping, turn-key engineering, and process development. Laboratories hosted in the ETRCs are also accessible by business sectors. The total revenue from technical services in ETRCs is about €7.8b (RMB70b) in 2010.

The main national programme in the rural part is the Spark Programme, which seeks to promote rural development through the application of science and technology. The programme regularly sends out science and technology *correspondents* to the countryside providing technical assistance to the farmers and rural enterprises. In addition, the correspondents recently have a mission of assisting rural entrepreneurship. The Spark programme served more than 6m farmers in 2010.

Several studies have examined knowledge circulation between science sectors (including universities and public research institutes) and enterprise sectors in the transition period of China's innovation system (Liu & White, 2001; Xue, 1997; Hong, 2008; Guan & He, 2007). For instance, based on a large national survey of science and technology activities in China, Motoharshi and Yun (2007) explored the interplay dynamics of S&T activities between enterprises and universities and PRIs using econometric analysis. They observed that both percentage of Chinese firms conducting R&D and the ratio of R&D to sales have increased dramatically over the period of 1996 to 2002. Utilising the database of United States Patent and Trademark Office (USPTO), Guan and his colleague investigated the contribution of science to technology and commercialisation based on non-patent references (NPR). They also found that China's patent connection to scientific research increased over their study period. And this trend was particularly pronounced in some technological fields such as biotechnology, pharmaceuticals, and organic fine chemistry.

## 2.7 OVERALL ASSESSMENT

The size of China's R&D workforce and the rate of investment in science and technology are making China a vibrant location for knowledge creation. China's research system is increasingly effective as well, reflected in recent indicators such as the world-leading number of scientific publications and citations indexed by major

science and engineering databases. Over the last five years, the national strategy of “indigenous innovation” has pushed the business sectors to the centre of the national innovation system. A key indicator of development is the high proportion of GERD funded by the business sector – 73%, similar to that in the US. Nevertheless, business R&D activities in China are still in the nascent stage. There are relatively few research output from the industry; R&D intensity is comparatively low, even in the high-tech sectors; and industry-university-research linkages are weak (State Council 2012).



## 3 National policies for R&D&I

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### 3.1 LABOUR MARKET FOR RESEARCHERS

#### 3.1.1 Stocks of researchers

China has 3.5m employees in science and technology occupations and 1.7m R&D workers (China S&T Yearbook 2011). According to the US National Science Foundation (NSF) Science and Engineering Indicators 2010 report, China has approximately as many researchers as the European Union, second only to the United States (Russo, 2010). China's R&D personnel topped 2.55 million person-years in 2010, reflecting a 15% growth rate over the last decade (*China Statistical Yearbook on S&T 2011*). According to the US National Science Foundation (NSF) Science and Engineering Indicators 2010 report China has approximately as many researchers as the European Union, second only to the United States (Russo, 2010).

Issued in 2011, the *National Medium- and Long-Term Plan for S&T Human Resource Development (2010-2020)* is currently the key strategic document addressing researcher development. The plan sets specific goals for the expansion of China's S&T workforce over the next ten years. These goals include: by 2020, the stock of researchers increases to beyond 2 million; the number of R&D personnel per thousand workers increases from the current 2.45 to 4.3; R&D expenditure per researcher increases from the current €0.05m (RMB0.44m) to €0.11m (RMB1m), approximately on par with the averages in the moderately developed countries.

The Hukou system – China's permanent household registration system – remains the main barriers to internal mobility of researchers. Nevertheless, repatriates with overseas degrees often receive preferential immigration policies from sub-national governments (See Section 4.6.1 for details).

#### 3.1.2 Providing attractive employment and working conditions

The average salary for Chinese college teachers is among the lowest in the world, or €517 (RMB4653) per month, according to a survey report conducted by Boston College's Centre for International Higher Education researchers (Altbach et al, 2012). But this is still much higher than salary levels of average city residents, whose monthly income was a mere average of €222 (RMB1998) in 2011 (National Bureau of Statistics, 2012). Most college teachers can afford a mid-income life. There are, however, significant inequalities among college teachers with different level of seniority and between teachers from elite universities and regular colleges. According to the same report by Altbach et al (2012), the newly hired Chinese college teachers earn as little as €186 (RMB1673.8) per month--only about a fourth of that of a senior faculty member, who can earn as high as €795 (RMB7154) per month on average. In recent years, elite universities in coastal China have offered globally competitive salaries to their faculty members. Researchers and teachers from regular universities, particularly those located in the hinterland, may be well below the national average.

The *Medium- and Long-term National Plan for S&T Human Resource Development (2010-2020)* promised several reforms to improve the employment conditions of the

research workforce, including: 1) improve the economic conditions and social status of S&T personnel in general via increased state funding to HEIs and PROs; 2) increase inward mobility towards the less-developed regions via raising allowances funded by national budget and providing government-funded positions; 3) implement a more open human resource strategy through improving the visa system and providing permanent residency to qualified foreign researchers.

In order to attract high-profile overseas Chinese researchers to return to the country, a set of regulations has been promulgated to provide better working conditions for them. These regulations provide globally competitive salaries, streamlined administrative procedures in employment, and priority for the schooling returnees' children and spouses' job hunting. Such packages often include a one-time relocation allowance and a start-up fund. The specific amount of this fund varies substantially by region, academic discipline, and the academic achievements of recruited scientists.

No evidence shows that career breaks (i.e. parental leave) are penalised in Chinese HEIs and PROs. Maternity leave is on average 90 days in China. For university teachers and researchers, it can be extended to 150 days. Women and minority groups have priority in promotion as well as presentation in academic and research committees, boards and governing bodies.

### **3.1.3 Open recruitment and portability of grants**

There are no legal barriers for non-nationals competing for permanent research and academic positions in China. China's language and culture do, however, present substantial obstacles to a non-Chinese researcher pursuing a career in China. This is particularly true for Chinese universities located in less developed regions. Among talents recruited into China, ethnic Chinese represent the majority. Another major barrier is the relatively lower payoff for research jobs in China, though the situation is improving and foreign researchers of non-Chinese origins have begun to show interest in working in Chinese universities, research institutions, and state-owned enterprises (Tang & Shapira, 2011; Zhao & Zhu, 2009). Visa requirements do exist but usually are not the determinant barrier.

The validation of foreign academic degrees of overseas Chinese students is required and regularly implemented by the Embassies and Consulates General of the People's Republic of China in countries that provided the education.

International advertising of research vacancies can occur, typically through international visiting of recruiting groups organised by the ministries or individual institutes.

Research grants are usually portable within China. No explicit information indicates whether portability remains if the researcher transfers to a foreign institution (so far these cases are rare).

### **3.1.4 Enhancing the training, skills and experience of researchers**

The Chinese education system has relatively standard practices for doctoral education. Doctoral programmes admit students through two main routes: one is through the national exam; the other is the exam-exempt admission, typically through Master-Doctoral programmes. The national exam includes standard tests for knowledge of current political affairs and English proficiency in addition to tests of disciplinary knowledge given by the department hosting the doctoral programme. The Chinese doctoral education typically involves coursework, oral defences of the dissertation, and a written dissertation. English education is a component of doctoral coursework. Mentoring doctoral students is a privilege, which the university grant to typically full professors and associate professors. More recently, there are exceptionally excellent assistant professors becoming doctoral mentors. With rapid expansion of doctoral education over the last ten years, there are concerns about potentially decreased quality of doctoral education, i.e. lack of attention from the mentors as many professors supervise more than ten doctoral students (Zhou et al., 2012).

The China Scholarship Council (CSC) provides funding and channels for joint graduate programmes between Chinese universities and overseas higher education institutions. There are some 185 currently active projects for studying abroad or academic exchange, serving senior research scholars, visiting scholars (including post-doctoral research), graduate students, mutual scholarship exchange with some countries, and special programmes.

### 3.2 RESEARCH INFRASTRUCTURES

The *National Science and Technology Infrastructure Programme* is the overarching roadmap for investing in national research infrastructure in China. Throughout the 11<sup>th</sup> Five-Year-Plan period (2006-2010), the government invested €206.65m (RMB1.859b) in the programme, with €41.7m (RMB375m) coming from sub-national governments. By 2011, China possessed an S&T infrastructure network with research equipment worth €3.34b (RMB30b) for public access. The network also hosts over 2,000 public R&D platforms and 3,000 enterprise R&D platforms. These platforms have specific missions for inter-regional integration and sharing of research infrastructure (MOST Annual Report 2011).

The State Key Laboratory programme organises major public and private laboratories receiving public funding in China. By 2010, there are 212 key laboratories hosted in HEIs and PROs, and another 96 hosted by business enterprises. The State Key Laboratories employ over 14,000 researchers, host R&D equipment worth €1.5b (RMB13.6b), and publish 20%-40% of all publications from China in top journals of their respective areas of research (MOST Annual Report 2011).

### 3.3 STRENGTHENING RESEARCH INSTITUTIONS

#### 3.3.1 Quality of National Higher Education System

China can claim 2,358 tertiary-level institutions. Over 22 million undergraduate students and 1.5 million post-graduate students enrolled in higher educational institutions in 2010. The combined number of undergraduate and post-graduate enrolment equates to approximately 1.7% of the population. The majority of the institutions are public universities governed by the central government and sub-national governments. Private universities and colleges account for a fourth of the total number of HEIs. But none of the private institutions offer post-graduate programmes.

In the 2009-2010 period, 2.8 million students graduated from higher education. Among them, about 1.8% of graduates received doctoral degrees. Gender distribution is fairly equal among all levels of higher education with the exception of doctoral level, where females account for a just 35% of graduates. The distribution of degrees across fields indicates that engineering accounts for 37% of bachelor's degrees, followed by business at 20% and literature at 14%. At post-graduate level engineering remains the most prevalent degree accounting for more than a third of Master's and degrees, followed by degrees in natural sciences.

More than 290,000 foreign students enrolled in Chinese HEIs in the 2010-2011 period. Among them, over 25,000 foreign students received scholarship from the Chinese government. Countries with the largest shares of non-Chinese student enrollees at Chinese HEIs are South Korea (21%), the US (8%), and Japan (6%).<sup>7</sup>

For a long period after the establishment of the People's Republic of China, the functions of Chinese universities were generally limited to teaching under the Soviet Union's central planning system. Only a few leading research universities participated in R&D, such as Tsinghua University and Peking University. In step with China's economic reform, its higher education system experienced dramatic changes after the first ten years of the Cultural Revolution. China resumed national college entrance tests in 1978. The Third Plenary Session of the 11th Communist Party of the China Central Committee was the watershed event for China's higher education development. But the major transition from elite higher education to mass higher education began in 1999, evidenced by the size of universities, the proportion of enrolment growth, and the extent of the autonomy for recruiting students and faculties.

Chinese universities are classified in a three-tier system, including key universities, regular universities, and two-to three-year colleges. Key universities and some of the regular universities offer graduate programmes and conduct R&D. The university system conducted around 10% of the national R&D in the last decade. R&D expenditure in universities increased from €2,693m (RMB24,230m) in 2005 to €6,639m (RMB59,730m) in 2010. Out of the R&D funds total in 2010, 60% came from government funds, 33% from industry, and 7% from other sources, including foreign funds.

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<sup>7</sup> Source: China Association for International Education. Accessed on October 17, 2012 from <http://www.cafsa.org.cn/index.php?mid=6>

In recent years, China has developed into a powerhouse in knowledge production, measured by academic research performance metrics. In 2009, China authored 127,532 Science Citation Index (SCI) papers and 97,877 Engineering Index papers, placing the country the 2<sup>nd</sup> and the 1<sup>st</sup> largest publishing country in the two indexes, respectively. Chinese-authored SCI papers have seen their impact factor steadily increase from 1.58 in 1995-1999 to 3.80 in 2005-2009. Co-authorship with researchers from other countries in China is about 27% in recent years, comparatively lower than the US (32%) and the largest European publishing countries (around 50%) but is on the rise (National Science Board 2012). The size of foreign students enrolled in Chinese universities has been increasing at an annual rate of 10% for a decade. In the Shanghai Academic Ranking of World Universities (2012), 28 of Chinese universities are among the world's top 500. The highest ranked Chinese universities are in the 151-200 range, including Peking University, Shanghai Jiao Tong University, Tsinghua Universities, and Zhejiang University. By field of excellence, the highest ranked Chinese universities are Peking University in Natural Sciences and Mathematics (76-100) and Social Science (101-150) and Tsinghua University in Engineering (39).

The quality assurance of Chinese universities is generally carried out through a top-down monitoring by the Ministry of Education and its sub-national branches. Universities entitled as state key universities or listed in national programmes (for example, 985 Programme and 211 Programme) are subjective to evaluations on a three- or four-year basis. Evaluation criteria include international rankings and output indicators such as number of SCI indexed publications and citations. Although the evaluation details are generally unavailable in the public domain, universities failing in the evaluation exercise would be dropped out of the programmes or demoted in lower tiers. Cases of universities failing evaluations are rare.

### **3.3.2 Academic autonomy**

There is a general lack of autonomy in Chinese universities in comparison with their counterparts in the West. The Ministry of Education organises the major aspects of teaching and research, decides on the appointment of university leadership in public universities and sets levels for tuition and fees in both public and private universities. For a few prestigious institutions (e.g. Peking University and Tsinghua University) university leadership is directly appointed by the State Council.

An increasing area of autonomy is seen in decisions to admit students and employ faculty members. The decision to recruit faculty members is made within the department or school and approved by the university, subject position availability. Universities are also allowed with limited but growing freedom in admitting students in addition to the admission through National College Entrance Examination.

### **3.3.3 Academic funding**

Data on the shares of block funding versus competitive funding allocated for academic teaching and research in Chinese universities is not disclosed to the public.



### 3.4 KNOWLEDGE TRANSFER

#### 3.4.1 Intellectual Property (IP) Policies

The Chinese law and policy system governing technology transfer is currently under transition. The Law of Promoting Technology Transfer issued in 1996 regulates research commercialisation in HEIs and PROs. It supports the rewarding of discoveries of new, commercially useful knowledge, and allows research contracts and patent licensing. However, this law had failed to define several critical aspects of rights and obligations for parties entering the technology transfers and transactions. The law is currently under investigation for amendments by the Ministry of Science and Technology<sup>8</sup>.

Technology transfer between Chinese HEIs/PROs and the industry occurs primarily through contracts for technology services, patent licensing and sales, and university-affiliated enterprises (Wu 2010). Entering into technology contracts with firms is the most significant mechanism of technology transfer for Chinese universities. Research contracts generate about 20% of university R&D revenue, followed by university-affiliated enterprises (10%) and patent licensing (2%) (Liu and Lundin 2007).

In most Chinese universities, technology transfer functions are subsumed under the S&T division, which traditionally manages a broad range of research activities. This approach gives insufficient attentions and staffing to research commercialisation. In 2001, the Chinese government established national technology transfer centres in six selected universities<sup>9</sup>. These national centres are staffed with professional managers and operate on independent budgets, thus they closely resemble the university technology transfer offices (TTO) in the West (Tang 2006). Nevertheless, the technology transfer centre approach has not been widely diffused in China.

There are both incentives and disincentives for the pursuit of intellectual property in Chinese universities. On the disincentive side, patenting is given less credit than scholarly publication in faculty promotion; and under the current Chinese patent law, universities and research institutes own the patents generated in academic research. On the incentive side, many universities subsidise the cost associated with patent application and maintenance. In addition, patenting licensing usually requires the inventor to share revenues with the institution/department. It is not uncommon for faculty to bypass the universities and work with firms directly through consultancy or other informal arrangements to maximise personal income (Wu 2010).

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<sup>8</sup> The Ministry of Science and Technology is investigating the revision of The Law of Promoting Technology Transfer. (People.com.cn 2010, Accessed on October 17, 2012 from <http://politics.people.com.cn/GB/1027/11342616.html>)

<sup>9</sup> The six universities are Central China University of Science and Technology, East China University of Science and Technology, Tsinghua University, Sichuan University, Shanghai Jiaotong University, and Xi'an Jiaotong University (Xinhuanet 2001, retrieved on October 17, 2012 from <http://www.edu.cn/20011122/3011306.shtml>).

### **3.4.2 Other policy measures aiming to promote public-private knowledge transfer**

#### **Spinoffs**

A number of approaches to facilitate technology transfer, university spinoffs and venture capital have been adopted at the local (i.e. city) and university level, varying by localities. These approaches include university-linked Science Park, industrialisation base, high-tech enterprise incubator, productivity promotion centres, and technology transfer centres. As noted above, few selected universities have established technology transfer centres similar to TTOs in the West, but the majority of Chinese universities are yet to develop institutional approaches to spinoffs.

In the Chinese S&T system, a prevalent approach to business creation is the establishment of university-affiliated enterprises (UAEs) (or university-run enterprises). The Chinese HEIs and PROs adopted this approach as a revenue-generating mechanism during the budget cuts in the 1980s. There are significant differences between the Chinese UAEs and the spinoffs seen in the West. The Chinese universities invest in and retain significant control over UAEs. UAEs are involved in, but not limited to, the research commercialisation activities (Euna et al 2006). In recent years, universities are generally seeking to exit the UAEs because of the conflict of interests in public universities and private ventures. Nevertheless, the UAE approach has given birth to a number of the largest Chinese high-tech firms, including Lenovo, Founder Technology Group, and Great Wall Computer (Lu 2000).

#### **Inter-sectoral mobility**

There are no legal restrictions but significant barriers exist in private sector researchers moving into academia. These barriers include the requirement of doctoral degrees, lower payoffs in academia jobs, and closed culture in the academia. There are exceptions in which successful people from the government or the private sector are invited to take professorship or administrative positions in universities. Yet, most of the honourable positions offered by universities are non-paid. Moving from academia to the private sector, however, is more common. University professors are generally allowed to work for industry on a part-time or consultancy basis. It is also not uncommon for a professor to run his or her spinoff companies while maintaining positions in HEIs and PROs.

#### **Promoting research institutions - SME interactions**

There are only few efforts to promote the interaction between research institutions and SMEs. Under the formal system the collaboration between university and enterprises is biased towards large firms, while neglecting SMEs to a large extent. SMEs, for example, usually are not able to be involved in joint-application for state research grants together with HEIs and PROs. It is not unusual, though, to have collaborative relations between university professors and private entrepreneurs. In many cases, university professors are interested in entrepreneurial activities to commercialise their research outcomes. Such activities are tolerated by the institutions in general. There are, however, no data available on the magnitude of these activities.



### **Involvement of private sector in the governance bodies of HEIs and PROs**

Chinese universities and PROs are primarily funded by the state and governed through a bureaucratic system. The private sector is generally excluded from the governance of HEIs and PROs. Private sector involvement in the form of industry advisory boards or councils commonly seen in the West is non-existent in Chinese universities, both public and private.

### **Regional Development policy**

The sub-national governments, i.e. a province or a city, are responsible for regional development policies under the sanction of the central. However, there are a few instruments organised by national programmes that have been widely adopted in China. The Touch Programme began in 1988, for example, and initiated the establishment of Science Parks (or High-tech Parks, High-tech Zones) as the primary tool to develop high-tech industries. There are currently 84 national Science Parks certificated by the Touch programme. Regional governments offer a range of preferential policies, including free land allocation, infrastructure, and facility support, as well as enhanced government services to firms in the parks. To be admitted into the Science Parks firms must be certificated as “High-tech Enterprises” by regional S&T regulators (i.e. regional departments of MOST). China’s largest and most advanced high-tech clusters have emerged from a few Science Parks, including Zhongguancun Science Park in Beijing, Zhangjiang High-tech Park in Shanghai, and Shenzhen High-tech Park in Guangdong.

## **3.5 ASSESSMENT**

The Chinese research institution system benefits from a large number of science and engineering researchers. Over the last decade, Chinese universities and public research organisations have been strengthened through investing in advanced research facilities and overseas recruitment of ethnic Chinese researchers. Increased enrolment in higher education institutes provides a strong base from which to transform China into an innovative society.

Significant gaps remain in the research system, however. Recent government strategic documents highlighted weak connections between research and the economy, few original innovations or inventions, low rates of research commercialisation, and a lack of incentives for innovation in the research system (State Council 2012). In the system, research expenditure on basic science accounts for only 5% of all research performed, a level consistent with technological catch-up and development but not enough for stimulating original innovation outlined in national strategy (Zaire et al 2011). Quality of higher education is an on-going concern given the rapid expansion of university enrolments (Zhou et al 2010). In addition, Chinese universities and PROs rely heavily on foreign trained returnee researchers to fill in the positions in their laboratories, while little evidence shows strengthening of home grown capabilities.

## 4 International R&D&I Cooperation

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### 4.1 MAIN FEATURES OF INTERNATIONAL COOPERATION POLICY

China's participation in international S&T cooperation is based on the understanding that opening up the S&T system and stepping into exchange and cooperation are necessary components of the nation's "reform & opening up" process. The Chinese leadership also recognises that, to move China's R&D&I capacity towards the global frontier, it requires "the integration with the global research enterprise, an open innovation environment, and the attraction of S&T resource from worldwide" (MOST 2011).

The primary interest of the Chinese government is setting framework conditions, i.e. participations in bilateral and multilateral S&T agreements. Research organisations, higher education institutions, business enterprises, and individual scientists are deemed the primary actors in international science and technology collaboration and cooperation (State Council 2006).

As indicated in the 12th S&T Five Year Plan, China has a keen interest in international cooperation in solving societal challenges including energy, environment, climate change, food security, disaster control and healthcare. The prioritised S&T fields are currently in energy, new materials, advanced manufacturing, information technology, agriculture, life science, environment, aerospace, and marine science.

### 4.2 NATIONAL PARTICIPATION IN INTERGOVERNMENTAL ORGANISATIONS AND SCHEMES

China participates in over 200 intergovernmental organisations and schemes in the science and technology domain. Primary examples include forums sponsored by UNESCO, the World Meteorological Organisation (WMO), the World Intellectual Property Organisation (WIPO), Food and Agriculture Organisation of the United Nations, the International Council for Science (ICSU), and the like. The primary actors in these schemes are Ministry of Science and Technology, National Natural Science Foundation of China, Chinese Academy of Sciences, China Association of Science and Technology, universities, research organisations and companies.

China participates in a number of large-scale research infrastructure programmes. China participated in building the Galileo satellite navigation system as a non-EU member. China is one of the seven member states in International Thermonuclear Experimental Reactor (ITER), the international nuclear fusion research and engineering project. China also has cooperation agreements with the European Organisation for Nuclear Research (CERN), and contributed to the accelerator construction costs of CERN's Large Hadron Collider.

### 4.3 COOPERATION WITH THE EU

#### 4.3.1 Participation in EU Framework Programmes

The EU Framework Programmes were officially opened to China in 1998, following the EU-China Science and Technology Agreement. China does not have a national strategy concerning participation in the EU Framework Programmes. Participation is based on decisions of individual researchers or research organisations, though applications are encouraged by MOST's International Science and Technology Cooperation Programme (ISTCP).

Until May 2012, Chinese participants were involved in 2,160 FP7 proposals of which 339 or 26% were awarded. These grants totalled €869m and involved 570 applicants.

In terms of successful applications, which reflect the relative strength of the national research system SP-3 PEOPLE ranks top as it represents the highest share of applicants in manifested proposals/applicants in all submitted proposals and the highest rate of success in terms of number of successful proposals. It is followed by Transport (TPT) and Knowledge Based Bio Economy (KBBE). Conversely, success rates (in terms of numbers) were very low in Energy and Social Sciences and Humanities ( a peculiar result, taking into consideration the emphasis of the country for harmonious development). Success rates were also very low in the ERC, JTIs, Regions, Science in Society, Fission and Fusion but this reflects differences in approaches rather than astonishing results. Success rates were 0 in Security (12 proposals and 17 applicants with no single success) and the one proposal in the Regions of Knowledge.

In terms of budget grant awards with China involvement in SP-1 was largest in the Information and Communication Technology (ICT) field, which comprised about a fourth of FP7 funding. It was followed by Knowledge Based Bio Economy (KBBE) comprising 20% of funding and Environment (ENV) with 13% of funding. Health was in a middle range, followed by Transport, NMP (Nanotechnology, Materials and New Processes) and Social Sciences and Humanities. This lack of similarity in shares of success and budgets indicates that Chinese application are probably composed of large consortia with large budgets.

#### 4.3.2 Bi- and multilateral agreements with EU countries

China has long standing bilateral agreements with Germany, France, the UK and Italy. More recently, smaller EU Member States, e.g. Austria, Denmark, Finland, Ireland, Norway, Sweden, The Netherlands, and Portugal, have intensified bilateral cooperation with China. Bilateral agreements with EU countries typically provide schemes for supporting the mobility of researchers, the establishment of joint institutional research structures, arrangements of collaborative research between funding organisations, research institutions, and government authorities. Areas of cooperation in these agreements include information technology, nanotechnologies, biotechnologies, and life science in the past years and energy, environment, and climate change more recently (Horvat and Lundin 2008). Primary examples of bilateral agreements between China and EU Member States may include the French

Programme for Cooperation with China (PFCC), France-China Particle Physics Laboratory (FCPPL), Sino-German Centre for Research Promotion, International Sino-German Transregional Collaborative Research Centres, UK-China Partners in Science (PiS), Sino-Dutch Centre for Preventive and Personalised Medicine, and NAMI (the China-Finland Nanotechnology Strategic Mutual Cooperation Initiative).

The Science and Technology Partnership Scheme established in 2009 between the Chinese Ministry of Science and Technology and the European Commission is currently the overarching scheme for the planning and coordination in the launching of joint strategic projects. The Partnership Scheme intends to provide guidance for further development in bi- and multilateral cooperation between China and EU countries.

#### 4.4 COOPERATION WITH NON EU COUNTRIES OR REGIONS

##### 4.4.1 Main Countries

China has bilateral cooperation agreements in science and technology with over 100 countries and regions. These agreements involve the major non-EU countries, including the US, Russia, Japan, Canada, Australia, South Korea and India. The agreements typically provide guidance on scientific exchange, research collaboration, and institutional structure for cooperation. The scope and scale of cooperation in these agreements vary significantly by country depending on areas of mutual interest. For example, under the framework of the US-China Agreement on Cooperation in Science and Technology established in 1979, there are currently over 50 active cooperation agreements between China and the US covering a broad range of natural science, social science, and engineering fields. As identified in the 3rd US-China Innovation Dialogue in May 2012, the US and China currently seek to solve societal challenges in agriculture, energy, environment, and climate change through joint efforts in science, technology and innovation.

China involves in a number of Joint Programmes at the regional level with East Asia, Central Asia, and Southeast Asia countries. Exemplary programmes include China-Japan-Korea Joint Research Collaboration Programme (JRCP), China-Central Asia Science and Technology Cooperation Centre, and China-ASEAN Agriculture Demonstration Base. By way of illustration, JRCP launched in 2009 is jointly funded by MOST, Japan Science and Technology Agency, and National Research Foundation of South Korea. JRCP supports collaborative research by researchers from China, Japan, and Korea in the areas of climate change, energy saving, disaster prevention, and water circulation.

##### 4.4.2 Main instruments

The International Science and Technology Cooperation Programme (ISTCP) initiated by MOST in 2001 is the national scheme for supporting international cooperation projects launched under China's bi- and multilateral S&T agreements with other countries. Its goal is to support Chinese scientists in international research activities.

ISTCP runs on an independent budget to cover cooperation projects, but it also serves as an umbrella scheme of integrating financial resources from major national S&T programmes such as “863” or “973” as well as from international funding sources. In 2010, ISTCP used its €175m (RMB1.57b) budget to support 470 cooperation projects. About a third of the participants are foreign nationals.

#### 4.5 OPENING UP OF NATIONAL R&D PROGRAMMES

The major Chinese R&D programmes (i.e. 973 Programme and 863 Programme) are open to foreign researchers or organisations. However, the national R&D programmes typically require one or more Chinese partners to apply for the grants jointly with foreign researchers. Funding of the collaborative projects usually has to go through the umbrella scheme of ISTCP. As mentioned above, a third of ISTCP’s budget is used to fund foreign researchers in recent years.

While usually neither the Chinese national R&D programmes nor ISTCP specifies the locational requirements, it is more common for foreign researchers or research teams to perform collaborative research at home. It is less common for foreign researchers or research teams to move to China to conduct research, partly due to the fact that China is yet to become an attractive location for researchers. However, there are national schemes, i.e. 111 Plan, to facilitate excellent foreign researchers to move to China (see section 4.6.1).

Policies to open up national programmes to foreign countries are generally neglected in the Chinese science and technology policy. Barriers for foreign researchers to participate in national research programmes lie in a relatively lower payoff of research jobs in China and visa restrictions.

The openness of the Chinese national R&D programmes to a particular country is typically specified in bilateral agreements. The Chinese national R&D programmes have been open to EU countries since the EU-China Science and Technology Agreement in 1998.

#### 4.6 RESEARCHER MOBILITY

##### 4.6.1 Mobility schemes for researchers from abroad

China currently possesses two main national schemes (111 Plan and Thousand Talents Programme). The goals of these programmes are attracting researchers from abroad and encouraging the return of nationals. The HEI Innovation and Talent Plan, or known as 111 Plan, initiated in 2006, seeks to attract 1,000 leading scholars from abroad to work in China’s top universities listed in the 985 Programme and 211 Programme. The ultimate goal of the plan is to build world-class universities in China. The central government has allocated a special grant of RMB600m (€66.7m) for the plan. By 2008, a hundred Innovation and Talent Centres were established in Chinese universities, providing cutting-edge research facilities and strong support to attract scholars to work in China.

The Thousand Talents Programme is the largest existing national scheme of attracting nationals to return. Introduced in December 2008, the Thousand Talents Programme aspires to recruit 2,000 Chinese national specialists to return and work on state-targeted areas. The programme has two categories for recruitment: an Innovation category, which recruits leading scientists and engineers to work in national key projects, key academic disciplines and key labs; and an Entrepreneur category, which targets business elites to start technologically sophisticated enterprises in key industries. Each of the specialists receives globally competitive compensation (RMB1m, or €0.11m) funded from the state budget. Through 2011, the Programme has recruited 1510 specialists worldwide, 1,161 of which are Innovation specialists, and 349 of which are Entrepreneurship specialists.

The Medium- and Long-term Plan for Human Resource Development (2010-2020) promised that a more liberal human resource scheme will be implemented in coming years. These schemes include allowing foreign nationals to work in higher-level positions in the government, improving the efficiency of the visa system, and provide permanent residency to qualified foreign nationals.

#### **4.6.2 Mobility schemes for national researches**

The China Scholarship Council (CSC) is the main government agency for sponsoring Chinese nationals to study abroad. CSC funds some 185 projects in five categories for overseas training. The five government-funded categories include senior research scholars, visiting scholars (including post-doctoral researchers), graduate students, mutual scholarship exchange to countries with government agreements, and special programmes (for cases not included in the other four categories). With increasing government funding, CSC now funds approximately 12,000 researchers annually to obtain training overseas. Half of funded researchers will pursue graduate degrees at host institutions, and half will become visiting scholars (including post-doctorate researchers).



## 5 CONCLUSIONS

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The progress in China's research and innovation system is underpinned by strong economic growth and the government's commitment to programs in science and technology. Amid the context of global recession, China is not only accelerating the rate of investment in R&D but also expanding the size of its already considerable research system. As outlined in the 12<sup>th</sup> S&T Plan and the MLP, the national R&D investment target is reaching an R&D intensity of 2.2% by 2015 and 2.5% by 2020. The Chinese government has promised an annual increase of more than 20% in government science and technology appropriation, and is encouraging business sectors to invest as well.

Current Chinese national research and innovation policies place emphasis on enhancing "indigenous innovation" capabilities and building a business-enterprise-centred national innovation system. Through national R&D programmes, government investment goes to over 60 prioritised science and technology fields highlighted in the MLP, including the thirteen national S&T mega projects. Innovation policy has seen continuous government support from the central and sub-national governments in the creation and growth of thirteen R&D intensive industries defined by the State Council as "emerging strategic industries". Expanding access to higher education and postgraduate education is the main priority of China's education policy, although lingering concerns exist about the quality of the higher education system.

With an increased funding, Chinese universities and public research institutions are significantly strengthened through investing in cutting-edge research facilities and overseas recruitment of ethnic Chinese researchers. With the implementation of the 2004-2010 National S&T Infrastructure and Facility Development Programme, China is building a network of research infrastructure for widened access. To move towards a business-centred innovation system, China is restructuring its research system to establish stronger linkages with the industry, reflected in the growing importance of the National Engineering Research Technology Centres in technology transfers. Knowledge circulation between China and advanced economies has been accelerated by increased funding for international exchange of researchers and students. China's linkages with the US in the domain of science and technology have been intensified through the establishment of annual US-China Innovation Dialogue, and a similar mechanism is close to being instituted between the EU and China as well.

By conventional measures, China is currently one of the largest contributors to knowledge production in the world. There are significant gaps in the Chinese research system, however. Despite a continuous government push, the business sector is yet to become central to the national innovation system. R&D intensity is low comparing to advanced economies, even in high-tech sectors. Recent government documents highlight the weak connection between research and the economy, few original innovations or inventions, low rates of research commercialisation, and a lack of incentives for innovation in China's research system (State Council 2012). In addition, Chinese universities and PROs are heavily reliant on foreign trained returnee researchers to fill positions in cutting-edge laboratories, while little evidence points to a strengthening of home grown capabilities.

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## 7 List of Abbreviations

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BERD	Business Expenditures for Research and Development
CAE	Chinese Academy of Engineering
CAS	Chinese Academy of Sciences
CERN	European Organisation for Nuclear Research
CSC	China Scholarship Council
FP	European Framework Programme for Research and Technology Development
EU	European Union
EU-27	European Union including 27 Member States
FDI	Foreign Direct Investments
FP	European Framework Programme for Research and Technology Development
FP7	7th Framework Programme
GERD	Gross Expenditure on Research and Development
111 Plan	HEI Innovation and Talent Plan
HEI	Higher education institutions
ISTCP	International Science and Technology Cooperation Programme
ITER	International Thermonuclear Experimental Reactor
JRCP	China-Japan-Korea Joint Research Collaboration Programme
LME	Large- and Medium-sized Enterprise
MLP	Medium- and Long-term National Plan for Science and Technology Development: 2006–2020
MIIT	Ministry of Industry and Information Technology
MOE	Ministry of Education
MOST	Ministry of Science and Technology
973 Programme	National Basic Research Programme
863 Programme	National High-Tech Research and Development Programme
NSFC	National Natural Science Foundation of China
PRO	Public Research Organisations
R&D	Research and Development
S&T	Science and Technology