COMMENTARY

China's innovation challenge

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ABSTRACT

China has made tremendous progress in building its science and technology capabilities. But to achieve its ambitions to become an innovation-oriented nation, the country has to challenge itself by establishing an enterprise-centered national innovation system, better spending the increasing sums of money on innovation, improving its intellectual property rights regime, overcoming talent shortage, and nurturing a culture of creativity.

Keywords: China, innovation, policy, intellectual property regime (IPR), IPR protection, talent, culture

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In the span of three decades, China has evolved from being a peripheral player to become the most potent engine in the global economy. Along with its rapid economic progress and the many improvements in the quality of life for large numbers of the Chinese population, a variety of indicators suggest that China's science and technology (S&T) capabilities also are on a sharply rising trajectory (Table 1). China started to restructure its S&T management system in the mid-1980s to make it quicker and better able to respond to the need of the economy. Since the 1990s, and especially 1995 when 'strengthening the nation through science, technology, and education' (*kejiao xingguo*) became a new development strategy, China's expenditure on research and development (R&D) has been increasing at a rate approximately twice that of overall economic growth. In 2007, China spent renminbi (RMB) 371 billion (USD 48.8 billion) on R&D, or 1.49% of its increasing gross domestic product (GDP), highest among countries with similar economic development level, though the percentage is still lower than that of most of the developed economies. This put China fourth in the world, after the US, Japan, and Germany.[1]

[1] According to OECD (2006) projections, using the purchasing power parity (PPP) measure, China became the world's second largest spender on R&D (USD 136 billion), ranking only behind the US (USD 330 billion). Of course, it should be noted that attempts to measure China's economic output in PPP terms are subject to debate, as its GDP based on that was reduced by forty percent in a recent recalibration. It also should be recognized that the gap in spending between China and the US remains substantial with the US spending more than three times that of the Chinese spending.
The preliminary data show that China's 2008 expenditure on R&D reached RMB 457 billion (USD 65.8 billion), or 1.52% of its GDP.

TABLE 1: CHINA'S SCIENCE, TECHNOLOGY, AND EDUCATION: SOME INDICATORS

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
R&D Expenditures										
Gross Expenditures on R&D (GERD) ($1billion)	6.65	8.20	10.80	12.60	15.56	18.61	27.75	29.91	36.79	37.10
GERD/GDP (%)	0.69	0.83	1.00	1.07	1.22	1.31	1.23	1.34	1.42	1.49
R&D Performance										
Enterprises (%)	44.83	49.59	59.96	60.43	61.18	62.37	66.83	68.32	71.08	72.28
Basic Research (%)	5.25	4.99	5.22	5.33	5.73	5.69	5.96	5.36	5.19	4.70
Papers Catalogued by *Science Citation Index*										
Share of the Total (%)	2.13	2.51	3.15	3.57	4.18	4.48	5.43	5.30	5.90	7.50
Rank in the World	12	10	8	8	6	6	5	5	5	3
Human Resources										
Scientists/Engineers Engaged in R&D (1,000 persons-year)	486	531	695	743	811	862	926	1,119	1,224	1,423
Graduate Student Enrollment (1,000 persons)	199	234	301	393	501	651	820	979	1,100	1,195
Undergraduate Student Enrollment (1 million persons)	3.41	4.09	5.56	7.19	9.03	11.09	13.33	15.62	17.39	18.85

Source: National Bureau of Statistics and Ministry of Science and Technology (comps.), *China Statistical Yearbook on Science and Technology* (Beijing: China Statistical Yearbook, various years).

Chinese institutions of higher education are turning out an increasing number of well-prepared graduates in science and technology. In 2007, China graduated some 194,000 students with master's and doctoral degrees, on top of 1.59 million engineering undergraduates as well as 231,000 science undergraduates (total graduating undergraduates reached 4.48 million). Unequivocally, this represents the world's highest output in terms of overall numbers.

In recent years, there also has been a steady increase in the number of high quality international papers published by Chinese scientists. Measured by the number of papers included into the *Science Citation Index (SCI)* – a bibliometric database published by Scientific Business of Thompson Reuters – in 2007, China ranked third in the world, after the US and the UK. In the same year, China overtook the US as the Number One contributor to papers catalogued by the *Engineering Index (EI)*. Although China still lags behind the world's leaders in many areas of science and technology, notable achievements have been recorded in a number of emerging fields such as genomics and nanotechnology. In nanotechnology, for example, in terms of published papers, China is second only to the US.[2]

China has witnessed a continuous growth in patent applications with the Patent Cooperation Treaty (PCT), an international patent law treaty. In 2008, China filed some 6,100 PCT applications, ranking it sixth in the world for the first time, after the US, Japan, Germany, South Korea, and France, but ahead of the UK. Huawei Technologies, China's largest telecommunications equipment maker, ranked first with 1,737 PCT

2 China is one of the six countries, others being developed ones, participating in the decoding of the human genomes at the turn of the century. On China's achievement in nanotechnology, see Zhou and Leydesdorff (2006).

patents filed in 2008, surpassing Panasonic of Japan; and another telecommunications equipment maker, ZTE, ranked 38th (WIPO 2009).

Foreign investment as well as imported technology and equipment continue to pour into China, making it one of the largest recipients of foreign capital and know-how in the world. And, most recently, many of the world's technologically most innovative companies have decided to move beyond setting up manufacturing facilities in China to establishing advanced R&D centers to develop new products and services for global markets as well as the Chinese domestic market. Of the more than 1,200 foreign R&D centers operating in China as of the end of 2007, over 300 were set up by the Fortune 500 companies.

In early 2006, with a great deal of fanfare, China's leadership issued a new 'Medium to Long-Term Plan for the Development of Science and Technology 2006–2020' (MLP). A remarkable package of policy initiatives in a variety of ways, the MLP builds on important S&T-related policy initiatives since the mid-1980s, including the *kejiao xingguo* strategy and the more recent notion of 'empowering the nation through talent' (*rencai xiangguo*). In addition to setting ambitious national priorities and formalizing the leadership's commitment to allocate substantial financial and human resources – to turn China into an innovation-oriented nation by 2020 – the MLP specifically defines enhancing indigenous innovation (*zizhu chuangxin*) capability, leapfrogging in key scientific disciplines, and utilizing S&T to support and lead future economic growth as its major objectives (Cao, Suttmeier, and Simon 2006).

In a word, once considered one of the more backward developing countries, China today stands as one of the world's most robust and dynamic economic and technology forces. These trends have led many observers to ask, in a similar vein, whether China also is poised to become a global leader in innovation.

Problems and vulnerabilities

With notable progress, mentioned above, attracting the attention of observers around the world, and many more achievements from the MLP implementation being expected in the coming years, a balanced perspective on the prospects for Chinese science, technology, and innovation requires attention to some of the challenges that China faces in realizing its ambitions.

First, China has yet to establish fully an enterprise-centered national innovation system. While overall statistics show that enterprises now account for close to three-quarters of China's R&D expenditures[3], in reality, China has allocated few financial resources to carry out innovative R&D activities. According to a comprehensive survey of the nation's R&D resources in 2000, the latest with detailed, micro-level information, firms within China's high-tech parks spent an average 1.9% of their sales on R&D, far below the 5% standard adopted by the Chinese to define a high-tech firm; those outside the parks spent merely 0.63%. Chinese enterprises as a whole do not do better, as they seem unwilling to spend money on technology development. According to 2007 statistics, only a quarter of large and medium-sized enterprises had set up S&T institutes, with only 1.58% of the sales revenue being used for S&T activities and 0.81% of revenue spent on R&D. Companies such as Huawei and ZTE, and BYD, a battery-maker-turned hybrid and electric automobile manufacturer, which do spend heavily on R&D, are the outliers, not the norm – in 2007, Huawei, alone filed 1,365 of the 5,470 PCT applications filed by Chinese firms (Zhang et al. 2009: xvi.). These few firms seem to have developed a more sophisticated approach to technological learning, knowledge acquisition, and intellectual property right (IPR) management, and seem to have realized in ways that most companies haven't that innovation is more than R&D; it requires the establishment of a culture of creativity that

[3] This increase in part reflects the fact that many government R&D institutes have been 'corporatized,' or converted into enterprises themselves.

rewards 'out of the box' thinking and entrepreneurial initiative.

In pursuing quick and short-term pay-offs, Chinese enterprises are keen to import foreign technology and equipment as the way to upgrade production technology; in such purchases, equipment dominates over software such as patents, know-how, blueprints, and so on. As a whole, Chinese enterprises spend more money on technology importation than on R&D. And once the equipment is imported, only limited financial resources are given to absorption, assimilation, and innovation, thus resulting in a vicious cycle of 'importing, lagging behind, importing again, and lagging behind again'.

Enterprises also lack sustained interest in engaging domestic institutions of learning for R&D efforts. The reform in the S&T system since the mid-1980s has to some extent activated the enthusiasm of researchers in these institutions (the supply side of technology), but enterprises (the demand side) have been reluctant to acquire technology from domestic sources. That is to say, there still is a long way to go to finding solutions to the deeply-rooted problems of the separation of innovation and the economy and of the organizational rigidity between enterprises and institutions of learning.

Second, it is frequently questionable whether the increasing sums of money provided by the Chinese government – central and increasingly local – have been well spent. As noted, enterprises seem mainly interested in acquiring technology from foreign sources. In addition, it is no secret that a significant portion of the research carried out in China, even those under the major national programs, is derivative of what has been done elsewhere, which surely has wasted increasing but still limited resources. This explains why Chinese science has not yielded significant breakthroughs commensurate with rising investments in R&D. While improvements are occurring all the time, however, citations to the increasing number of Chinese S&T papers have been quite disappointing.

Misuse of research funds also is commonplace. More seriously, corruption in scientific research has not only eaten up a not-so-small-part of funds, but also eroded the morale of the research community as cases of fraud and misappropriation of funds surface in the media and on the internet. For example, in 2006, Dr Chen Jin from Shanghai Jiaotong University was found to have secured hundreds of millions worth of funds from various government agencies, including the Ministry of Science and Technology, the then Ministry of Information Industry, and the National Development and Reform Commission, for semiconductor research; it was discovered, unfortunately, that he was using a purchased chip as his innovation. Chen Jin was fired by the university, had his various honors removed, and had to return a portion of the research money, but Chen himself never was prosecuted for his cheating. Many members of the Chinese research community have believed that the Chen Jin case is just the tip of the iceberg in research misconduct. Fortunately, the government agencies involved carried out a thorough investigation and have tried to implement changes to prevent further opportunities for similar mis-directed behaviors (Barboza 2006; Hao 2006).

Therefore, with the MLP supporting mega science and engineering programs, each of which will receive investment at the scale of billions of RMB, and with the revised Law on the Progress of Science and Technology promoting greater innovation and creativity by fostering a 'tolerance for failure' (Hao 2007), the question of financial integrity and accountability looms large as a fundamental issue of governance in scientific research. It also relates to whether China will eventually achieve its ambitious goals and play a more significant role in the frontier of international science and technology. There has been a rush to spend the money allocated to the mega science and engineering programs while a vigorous peer review process to guarantee the quality lags behind.

Along with the financial management issues, there is a major drive underway to create a new economic development model that is not so capital-intensive, low-cost labor-oriented, and gobbles up natural resources. It is in this sense that one of China's senior science policy-makers commented that the research community will not have another opportunity if it does not succeed in implementation of the MLP. But, its ability to succeed still is constrained by weak links to users – whether commercial firms competing in the marketplace or government agencies seeking to provide the technology-embodying public goods – where China needs strong links for a more sustainable developmental model.

Third, China still has a long way to go to improve its intellectual property regime (IPR). At first glance, China's IPR laws and regulations are as perfect as those promulgated by other countries; the problem lies in the enforcement. In fact, a decentralized China has made IPR protection at the local level difficult, if not impossible.[4] China's weakness in IPR protection has been a major concern for numerous foreign companies. But entering the 21st century, two of the three key initiatives – patents and technical standards – put forward by China's scientific leadership are IPR-related (the other is about the development of talent) (Suttmeier, Yao, and Tan 2006). This is not only because the leadership realizes that China needs to be more responsive to the operating standards of the current international IPR regime. Just as important, to be a serious player in global innovation, China has to generate its own IPR. In other words, China itself will not become innovative unless it takes more seriously the issue of IPR protection.

Fourth, though not intuitively obvious, there is a shortage of qualified personnel that has arisen because of a serious 'brain drain' of Chinese talent to foreign countries and most recently and noticeably to foreign-invested enterprises in China, including their R&D operations. Thus, China faces a serious talent challenge as it seeks to sustain domestic economic growth and promote technological advance (Simon and Cao 2009). There is little doubt that China's current S&T talent pool is impressive: the number of scientists and engineers in China is the world's second largest, after only the US; the evolving pipeline seemingly remains full as Chinese universities graduate the world's largest number of students; and the quality of graduates from key Chinese institutions of higher education is internationally acclaimed. Despite all this, complaints continue to proliferate from multiple segments of the economy and society – from among Chinese government officials to enterprise CEOs, including the country heads of most MNCs that operate in China – about the shortcomings that plague the local talent pool. Demand seems to be exceeding supply, quality problems are rampant, distribution is uneven, and the talent already in place remains difficult to manage and retain.

The active members of China's professional community are young when compared to their counterparts in the West – many being recently out of school – so they lack the concomitant experience of their peers abroad, especially in many leadership positions in the Chinese research system. China's talent challenge is most serious in the 50 to 60 year-old group and at the high end of the talent spectrum. In fields as well as geographic locations where there is an apparent surplus of professionals, many problems limit the value and impact of these individuals. In some instances there is a gap between the knowledge students acquired in college and the requisite skills needed for their jobs. All too often, the structure and distribution of the talent pool at senior, middle, and junior levels is misaligned or does not match up well in terms of disciplines with the exact skill needs of the immediate geographic region. And as Chinese society has begun

[4] Although a number of Chinese enterprises have recently been sued over IPR infringements, most have been unsophisticated cases of copyright violations or making fake products – with some exceptions such as Huawei, which several years ago was accused by Cisco Systems, the world's leading networking and communications manufacturer, of patent infringement.

to age as well, the changing demographic composition of the professionals in terms of age and work experience also has started to have an impact on the potential for progress in the future.

The talent shortage could have a negative impact in the near-to-medium term. The ability of employers to attract 'the best and the brightest' will be affected by the shortage and China could experience the onset of a real 'talent war.' Foreign direct investment (FDI) will continue to be one of the key drivers for the demand of scientists and engineers in China, and if there is not enough talent available for foreign-invested enterprises, desired types of higher value-added FDI might not materialize. Consequently, China's pace of economic growth, especially in terms of the development of new, technology-intensive sectors, might be jeopardized.

China's capacity for overcoming its S&T talent shortage, including its ability to provide training-related quality improvements, will determine the extent to which it can develop indigenous innovation capabilities and reduce its current dependency on foreign technology and invention. These are the critical MLP mandates. It is under these circumstances that a rapid response is needed to moderate, if not ameliorate the prevailing experience and skills gap.

The Chinese leadership surely has realized the significance and urgency of the talent issue, reflected in the fact that the Chinese Communist Party (CCP) held its first talent conference in late 2003, during which the General Secretary Hu Jintao said that 'today, the heightened international competition boils down to a competition for human resources'. Indeed, a number of programs, such as the One Hundred Talent Program at the Chinese Academy of Sciences and the Cheung Kong Scholar Program at the Ministry of Education, offering generous incentives, have been initiated to recruit Chinese scientists and other professionals working abroad to come back to China, and as the condition of the Chinese research environment continues to improve, it is expected that the volume of the 'reverse brain drain' will increase. Recently, the CCP Central Committee launched another program, the Thousands Talent Program, pledging to attract some 2,000 high-end Chinese talent residing overseas in the next five to ten years.

Last but not least, there is the question of whether China can become an innovation-oriented nation without being open to different ways of thinking. This is more than just a philosophical question. While on the surface Chinese researchers and entrepreneurs are encouraged to think outside the box and not to be afraid of failure, at least equally important is that other ingredients of a true innovation culture – autonomy, free access to and flow of information, and especially dissent, scientific as well as political – are not adequately applauded or tolerated. In the field of innovation, it is generally believed that tolerance is as critical as talent and technology in driving creativity and growth (Florida 2003). For example, Thomas L. Friedman, the *New York Times*' columnist, has stated that censoring Google in China is equivalent to 'curtailing people's ability to imagine and try anything they want' (2006). Therefore, allowing 'blooming and contending' is more important than purely worshiping innovation as a new 'religion'. If the former is not allowed, the potential success of China's innovation strategy will be called into question. It is in this vein that China's innovation pursuits may be in conflict with the government's other goal, that is, the construction of a harmonious society; innovation often requires running against the tide rather than simply going with the flow.

In a word, while China's efforts to become an innovation-oriented nation certainly have the potential to change the complexion and landscape of the international science and innovation regime, it also is the case that China faces numerous internal challenges that must be addressed sooner rather than later if Chinese stated goals and objectives are to be realized. As indicated above, Chinese leaders and S&T policymakers should be given great credit for the substantial progress that China has made over these last twoplus decades. Nonetheless, more attention needs to be paid to the 'software' side of the innovation equation so that a true 'culture of creativity' can be inaugurated, implemented, and nurtured across the full spectrum of national and local-level Chinese S&T organizations and institutions. Only with this 'culture of creativity' in place can China's efforts to re-orient its economy and S&T system acquire needed traction and build the necessary forward momentum.

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