The World upside down, China's R&D and innovation strategy

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fondation maison des sciences de l'homme

Séminaire BRICs FMSH-CRBC

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N°7 | avril 2012

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Working Papers Series

Fondation Maison des sciences de l'homme - 190 avenue de France - 75013 Paris - France
http://www.msh-paris.fr - FMSH-WP-2012-07

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february 2012

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The text

This texte was presented on the 14th of november 2011, at a seminar about BRICs, which is held collaboratively by the Centre de recherche sur le Brésil contemporain (CRBC-EHESS) and the Fondation Maison des sciences de l'homme.

Pour citer ce document

Guilhem Fabre & Stéphane Grumbach, *The World upside down,China's R&D and innovation strategy,* FMSH-WP-2012-07, avril 2012.

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http://halshs.archives-ouvertes.fr/FMSH-WP
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Abstract

R&D and innovation have become much more strategic than ever before for the growth of China as well as for its global societal upgrade. The Chinese authorities have designed an innovation strategy to face new economic and social challenges. The first part of the paper is focused on the emergence of the policy, in the 2006-2020 Plan for S&T, with a historical perspective explaining the legacy of the past in today's choices. In the second part, we illustrate China's catching up strategy through four sectors (high-speed trains, aeronautics, clean energy, IT) and discuss its potential impact on the world industry.

Keywords

R&D, innovation, strategy, high speed trains, aeronautics, clean energy, IT

Résumé

La R&D et l'innovation sont plus stratégiques que jamais pour la croissance de la Chine aussi bien que pour le progrès global de sa société. Les autorités chinoises ont mis en place une stratégie d'innovation pour affronter de nouveaux défis économiques et sociaux. La première partie de ce papier se concentre sur l'émergence de cette politique, dans le Plan de 2006-2020 pour les Sciences et Techniques, avec une perspective historique qui explique l'héritage du passé dans les choix contemporains. Dans la seconde partie, nous illustrons la stratégie de rattrapage de la Chine dans quatre secteurs (les trains à grande vitesse, l'aéronautique, l'énergie propre et technologies de l'information) et discutons de ses impacts potentiels sur l'industrie dans le monde.

Mots-clefs

recherche et développement, innovation, stragégie, train à grande vitesse, aéronautique, énergie propre, technologies de l'information

Introduction

In 2010, China became the world's largest manufacturing nation (19.8 % of the world manufacturing output) bypassing the US (19.4 %), thus ending its 110 year-run as the largest producer of goods[1]. After joining the WTO in 2001, China's growth during its golden period (2002-2007) was driven mainly by fixed asset investment and exports, whose average annual growth rates were respectively 29 and 24 percent. Following the spread of the US financial crisis around the world, the fall of global demand revealed China's high export dependency. Meanwhile, the government's stimulus package, based on expansionary fiscal and monetary policy to maintain economic growth, raised the investment rate from 25 % to 46 % of GDP from 2001 to 2010, leading to an overcapacity in certain sectors, a decline in efficiency[2], inflation and wage pressure, which reflect the general imbalance between investment and consumption.

China's investment and export led growth is largely dependent on the supply of cheap labor from the hinterland, in a context of stunted urbanization resulting from the Maoist policies (1949 to 1979). This compelling illustration of Arthur Lewis' development model, whereby the transfer of an unlimited supply of labor in the traditional sectors feeds accumulation in the modern sectors through urbanization dynamics[3] has been challenged for several reasons. First of all, in 2004 and 2007 there was a shortage of labor, partly due to the absence of any social insurance for the massive migrant population, in the Pearl River Delta Region of Guangdong province, which concentrates some 30 % of foreign investments and exports, and 10 % of GDP between Canton, Shenzhen and Zhuhai, the two special economic zones at the borders of Hong Kong and Macao. Although this shortage of labor often takes the form of high turnover rates, and an imbalance of female employment, generally more docile and required for precision processing than male employment (the ratio between young women and men is in the order of 117 to 100), this trend will increase in the future. United Nations projections show that in the 15 years from 2010 to 2025, the pool of 15 to 24 year old, which provides the bulk of labor-intensive activities, will fall, as a result of the one-child policy, by almost 62 million people to a total of 164 million[4].

Second, China has seen double-digit annual growth of real salaries, partly due to the multiplication of work conflicts before and after the slowdown of 2008-2009. According to a Chinese survey in different provinces, 80 % of migrants in 2007 were paid less than 800 Yuan (105 $US) per month, and two thirds of them were working 300 hours per month. As shown in (Xu Xianjin, 2007; Artus, Mistral, Pagnol, 2011 p.62) in 2011, the minimum wage for Guangdong satellite cities increased to 1100 Yuan (162 $US) after the strikes of 2010, and was raised again in Shenzhen to 1320 Yuan (200 $US)[5]. Moreover, nearly half of the 200 million migrant workers, born after 1980, are better-educated, with an average education of about ten years, they use the Internet and new technologies, and are more demanding than their parents. World Bank analysts believe that China could become a high-income country by 2030[6].

Third, since 2000, the cost of land has increased drastically, and even more so after the 2008 crisis, when land was used to finance the local part of the stimulus package, which led to a predictable property bubble, in the absence of any land tax. Last, but not least, the cost of energy, which accounts for a third of the cost of grain production, has also risen dramatically, to the point that China's crude oil imports, in 2011, may exceed what it earns selling goods to the United States. If we add the competitiveness loss due to the reevaluation of the Renminbi to the US dollar, combined with inflation pressures, it is clear that China's high investment and export-led growth model is no longer sustainable. Products, which are not classified as high-tech, still account for 68 % of China's exports in 2010 (1.09 trillion $US) a small change from the 71 % share in 2005. China's light manufacturing share of the US and European Union imports started to decline in the first half of 2011 from 50 % to 48 %, in favor for instance of Bangladesh (up 19 % in exports to the US) or Vietnam (up 16 %)[7].

1. Study of IHS Global Insight, cited in Financial Times, 13/03/2011.

2. Yu Yongding, (2009).

3. Lewis, Arthur, (1954)

4. Bloomberg News, 30/08/2011.

5. Jacob, R. *Financial Times*, 6/09/2011.

6. *China 2030: Building a Modern, Harmonious, and Creative High-Income Society*, World Bank Report, Feb 2012.

7. Bloomberg, 30/08/2011; Rahul Jacob, *Financial Times*, 6/09/2011.

This quadruple shock, in terms of costs, exchange rate, labor, energy and land, increased the role of China's R&D and innovation policy as the main strategy for climbing the value chain, as Japan and the four dragons had previously done in the mid 1980s. The US Department of Commerce estimates that 75 % of the growth in the American economy since World War II is due to technological innovation (Glassman, 2010).

To restore its competition and national strength, to reach the goal of China's renaissance, the country should not only improve its « hard power », which refers to the nation's economic, scientific, technological and military power, but also its « soft power », viewed as a national sense of unity, the population's education level and the nation's role in and impact on international affairs. In 2005, indigenous innovation was also conceived as an answer to the strategic place taken by China in the internationalization of R&D led by transnational corporations, as underlined by the 2005 UNCTAD World Investment Report focusing on this issue[8].

The paper is organized as follows. In the first part, we introduce the innovation policy and its new strategic orientation as presented in the 2020 Plan for S&T, established after the fourth conference on S&T organized since 1949. We give a historical perspective on the development of S&T in China, which helps understand the current setting. The following section is devoted to four areas, where China has been successful in recent years, high-speed trains, aeronautics, clean energy, and IT, which illustrate the implementation of the new Chinese policy, and its impact in the world.

« The real leap forward »

Or the transition from low-cost labor to technology-intensive growth

Although science and technology were a key part of the « four modernizations » program launched by Deng Xiaoping when he rose to power in 1978-79, the « real leap forward » in S&T really began after 2000. It contrasts drastically with the catastrophic Great Leap forward of 1958-1959, which was based on the negation of science and technology, and more generally of simple practical evidence. Nowadays, China's leaders are extremely accurate on technology issues, as eight of the nine members of the Communist Party Political Bureau have engineering degrees. They perceive innovation and competition as the two sides of the same coin, and consider technological innovation as a strong mean to fuel long-term growth.

Following intense debates at the central level, the release of a « National Medium and Long–term Plan for Science and Technology Development (2006-2020) » in early 2006, (hereafter the 2020 Plan), aims to derive by the end of the decade 60 % or more of China's economic growth from technological progress, and to catch up with more advanced countries. "Innovation with Chinese characteristics" or "indigenous innovation" became the motto of the "second stage of the opening and reform policy" led by the tandem Hu Jintao -- Wen Jiabao (Mc Gregor, 2011). A glimpse at the historical development of science in China helps understand the current debates, fueled by national pride and distrust of foreigners.

A historical perspective

The efforts of China to catch up in science and technology, which have increased continuously since the early days of the Deng era, started several centuries ago. Modern science, developed in Europe, started penetrating China in the second half of the 16th century, towards the end of the Ming dynasty (1368-1644), under the influence of the Jesuits who contributed to introduce mathematics, astronomy, and geography among other fields, and enjoyed great respect in particular for their deep understanding of issues related to calendar making.

When western science was introduced in China, Chinese science and technology lagged far behind. Nothing similar to the scientific revolution that took place in Europe had happened in China. However, there was a scientific activity, with some remarkable breakthroughs such as a smallpox vaccine developed in the 16th century, long before this type of inoculation was discovered in Europe, or a precise measure of the earth meridian in the early 18th century.

The technological supremacy of the West allowed it to impose its colonial will on the last Manchu (Qing), dynasty (1644-1911) in the 19th century. During the first Opium War of 1840, the British

8. UNCTAD World Investment Report 2005, available online, hereafter WIR 2005.

Navy tested its newest technology by sending the *Nemesis*, the first ocean-going iron-warship, launched in 1839 for the East India Company. Mastering military technologies became crucial for China, which tried, just like Japan, to adapt to modernity by launching a new movement of "occidental affairs" (*yangwu yundong*) where Chinese culture was seen as the base and occidental science and technology including military technology, were regarded as purely instrumental. The awareness of this period is particularly strong in contemporary China.

In the first half of the 20th century, China underwent a strong influence of foreign culture, carried by the numerous students coming back from Japan, the US or Europe, in all fields, including humanities. Scientific universities were founded, such as Tsinghua in 1911, with the aim of training students that would continue their curriculum in the US. Traditional Chinese culture, mostly Confucianism, was seen as an obstacle to modernity during the nationalist May 4th movement (1919), which promoted democracy and science and opened the way to a cultural renaissance in literature, arts and urban life styles. In 1928, the new nationalist government created the Academia Sinica, the first national institution devoted to scientific research.

After the establishment of the People's Republic in 1949, scientific research is reorganized with the help of the Soviet Union, with a strongly centralized model around the Academy of sciences, the universities, the technical institutions depending from the various ministries -- particularly the ministry of defense, which concentrates most of the effort -- and their provincial affiliates. The USSR sent more than 10,000 scientists and technicians to assist China in its technological development, while around 40,000 Chinese students were trained in the Soviet Union. The decisive support from the USSR played a key role during that period, especially in defense related domains, with the space conquest and the atomic bomb.

After 1949, the scientific policy of China was designed during national conferences on S&T that took place in 1956, 1978, 1995, and 2005. Numerous scientific institutions were founded in 1956 after the first national conference on S&T, during which the decision was taken to create a commission for S&T that later became the Ministry of Science and Technology, MOST.

After the Sino-Soviet dispute at the turn of the 60's, the achievements of the People's Republic are mostly military, with the explosion of the first A-bomb in 1964, the H-bomb in 1967, and the first launching of a satellite, Red Orient, by a Long March rocket in 1970. One of the most important scientific achievements made by China might have been the synthesis of insulin, a real breakthrough, made during the early 1960's by a scientist trained in the UK, and which could have been awarded an international prize such as the Nobel, if the Cultural Revolution had not put an end to the work of all civilian scientific institutions.

Despite these military achievements, the high peak of the Maoist period (1957-1976), from the anti-rightist campaign (1957) to the Great Leap Forward (1958-1961) and the Cultural Revolution (1966-1976) is mainly characterized by the negation of science and technology, and the apology of political will (the famous slogan "Rather red than expert") directly responsible for the persecution of hundreds of thousands of intellectuals, for a gigantic waste of resources, for the most terrible famine of the century (1959-1961), and for technological underdevelopment.

Catching up becomes one of the top priorities of Deng Xiaoping when he returns to power after the death of Mao, and launches the reform and opening policy. The second national conference on S&T is organized in 1978, with the slogan: "science and technology: first production force". Universities are reopened as well as research centers, and intellectuals reintegrated in the workforce. One of the visionary decisions of Deng is to send immediately thousands, tens of thousands and finally hundreds of thousands of students abroad. Such a policy had an extremely high cost, dried up China from its best students, with no immediate return, but constituted an incredible long-term investment. Agreements of scientific and technological cooperation are signed with most developed countries in 1978, soon followed by agreements between foreign and Chinese scientific institutions, while Chinese scientists join most international science organizations.

Several important programs, still at the core of the Chinese innovation system today, were created in the mid 80s, such as the State Key Lab program, launched in 1984, for laboratories on key topics directly supported by the Ministry of Science and Technology (MOST), the 863 program, in 1986, for high-tech research, mainly oriented towards export, the Torch program, in 1988, for the establishment of technological parks, etc. Unlike the previous institutions based on Soviet planning, these programs have been inspired by various research systems worldwide. China has developed an impressive capacity to learn from abroad to settle its new organizations. One of the best examples of this dynamic is the decision to create in 1986 the Natural Science Foundation of China (NSFC), independent from the very political Ministry of Science and Technology, on the basis of the American National Science Foundation.

The third national conference on S&T took place in 1995, with the objective of refocusing research institutions towards their original missions and improve their quality. The bold reform of the Academy of Sciences that followed, contributed to the modernization of the most prominent scientific structures, with a 12-year program (1998-2010), organized around three phases: a first phase where about a third of the institutes were closed down (84 institutes versus 119 before the reform), a second phase where the remaining institutes were consolidated, and a third phase, with the creation of new institutes, many of them in the fields of life sciences. The Pasteur Institute of Shanghai is one of them. One of the keys of this reform has been the systematic organization of the reverse brain drain, with very interesting programs to support what the Chinese call the "turtles", the returnees, mostly from the US, as well as the scientists, who while they stay abroad, occupy visiting positions. The returnees are now numerous in all the labs, public and private, either Chinese or belongings to transnational corporations (TNCs), where they often have important positions, heading most of the research labs of TNCs, Microsoft, Nokia, etc.

The turn of the millenium

The best proof of China's radical evolution in the last decade is the dramatic increase in higher education and human resources mostly in engineering. The percentage of young age cohorts enrolled in university curricula, between 2000 and 2008, rose from 11 % to 35 %, and the number of graduates increased from 1.7 million to more than 7 million. About 39 % of students concentrate on a scientific curriculum in comparison to 5 % in the U.S. There were 700,000 Chinese graduates in engineering degrees in comparison to 80,000 in the U.S. The share of the active population with a university-level education[9] is now comparable to the Euro zone (26 %), but the absolute number is striking (now more than 100 million), as well as the number of currently enrolled Chinese students (25 million out of 140 million worldwide) (Arthus, 2011, p.17, 292).

Between 2000 and 2010, China's R&D expenditure doubled as a share of GDP (0,8 % to 1.75 %) and R&D personnel increased from about one million (full-time equivalent) to 2.8 million[10.] At the end of the decade, its share of total global R&D spending equaled Japan's in purchasing power parity (12.3 %) just behind the US (34.4 %) and Europe (23.3 %). China's world share of researchers was equal to the US (20 %, with 1.4 million) in 2007, just behind Europe (30 %, with 2.1 million) but the rapid increase of R&D personnel during the crisis allowed it to catch up with Europe[11]. Nobel Prize winning economist Robert Fogel of the University of Chicago estimates that in the US, a high school educated worker is 1.8 times as productive and a college graduate, 3 times as productive as someone with a ninth grade education. On this basis, he believes that the increase in high skilled workers will substantially boost China's annual growth rate for a generation[12].

The quality of China's education has also improved, with the creation of the C9 League, a club like the US Ivy League, which includes the top universities, and with the adoption of a bold policy of internationalization of studies. In 2010, the total number of Chinese students and scholars attending foreign universities or research institutes rose to 284,700, thirteen times more than in 1999. Chinese students comprise the highest share of foreign students in the US, the European Union as well as Japan. At the end of 2010, according to the Ministry of Education, China had the largest oversea student population in the world, with 1.27 million Chinese studying or having

9. Alain Berder, «La Chine : laboratoire du monde ?», *Trésor-Eco*, 60, juin 2009.

10. Wu, Yanrui (2011), and (2010).

11. Martin Grueber, « 2011 Global R&D Forecast », *R&D Magazine* December 2010, p. 3, available at www.rdmag.com; Wu, Yanrui (2011): in 2010, they were 2.8 million R&D personnel, but we can deduce from previous data that 70 % (or 1.9 million) are effective researchers.

12. « 2011 Global R&D Funding Forecast », *R&D Magazine*, December 2010, p.28, www.rdmag.com

studied abroad, among whom many do not return. According to the latest census data, more than 700,000 highly skilled residents in OECD countries were Chinese-born, 57% of whom were living in the United States[13].

Nothing is more symptomatic of the qualitative change of the last decade than the recent activism of China towards intellectual property. According to the World Intellectual Property Organization, the applications for international patents by China have tripled between 2006 and 2010, representing 7.5% of the world total. They concern mainly electrical engineering, telecommunication and informatics (58 %), chemicals, biotechnology and drugs (21 %)[14]. In Europe, China seems hyper specialized in telecommunications, as its share of patents submission was 4.3 % in 2008. In the US patent system, China is specialized in spatial armaments, with a progression of 672 % of patents delivered between 2003 and 2008. A recent WIPO report shows that China and the US accounted for most (4/5) of the growth in patent filings in 2010[15]. As for the scientific publication production, between 2003 and 2008, China bypassed Japan, still lagging behind the European Union and the US, rather strong in mathematics, engineering sciences, physics, chemistry, but much weaker in life sciences[16].

Transnational Corporations are key players since they account for about half of global R&D and at least two thirds of business R&D expenditures (estimated at 450 billion $US in 2005). R&D spending of some large TNC's is higher than that of many countries, as six of them, concentrated in a few industries (IT hardware, automotive, pharmaceutical and biotechnology) spent more than 5 billion $US on R&D in 2003 (Ford, Pfizer, Daimler Chrysler, Siemens, Toyota, GM). The share of R&D of their majority owned foreign affiliates, varied from 13% for the US to 43 % in the case of Sweden, in the first years of the new century. During the period 2002-2004, developing Asia and Oceania took over half of the FDI projects involving R&D worldwide, and China, which had already around 700 foreign R&D units in 2005, was mentioned by the largest number of TNC's as the main destination for R&D future expansion, before the US and India[17].

The internationalization of R&D in China was driven by the need to adapt products and processes to key host-markets (*adaptive R&D*), to monitor the activities of competitors, but also in a first phase, by the quest for R&D cost reduction as well as to access expanding pools of talents. Internationalization might create potential tensions between the TNC's and the host country's governments « in that the former may seek to retain proprietary knowledge while the latter seeks to secure as many spillovers as possible ». The key determinant is therefore the *absorptive capacity* of the host country, the type of R&D conducted, and its links to production. « The more a TNC interacts with a host developing country's local firms and R&D institutions, and the more advanced the country's national innovation system, the greater the likelihood of positive effects on a host economy »[18]. In other words, there are no more closed frontiers or strict labor divisions between the « innovators » and the « commodity providers ». The commodity providers at low prices may also become innovators at low prices, for competitive products targeting the emerging markets for instance.

TNC's expand R&D in China to tap the vast pool of talents and ideas and to stay abreast of competitors in the increasingly sophisticated markets of China and Asia. The supply of talented manpower exceeds foreign firms demand, universities and research institutes are eager to get funding from private firms, the high-technology parks, the governmental incentives and the potential to reduce costs across all the stages of the R&D value chain, tend to shift TNCs R&D labs from support and adaptation to full-scale R&D work using China's emerging technologies and talent pools[19]. The turn of the millennium was confirmed in the second half of the decade, as the pace of R&D investment growth in China was 20 % a

13. *R&D Magazine*, December 2010, p.27; According to different figures, Chinese students represented 13.6 % of foreign students in the European Union in 2005, their main destination, with an enrolment of 109,000, versus 92,000 in the US (*Trésor-Eco*, n°60, p.3); Chen Jia, *China Daily*, 18/04/2011; Martin Schaaper, (2009), p.4.

14. Carta IEDI n°482, 26/08/2011, A transformaça da China em economia orientada à inovaçao, Parte 1, p.21, available online. (Excellent bibliography)

15. WIPO, World Intellectual Property Indicators, 2011 edition.

16. 中国科技论文统计结果 *2009;* Observatoire des Sciences et Techniques, *Rapport Bi-annuel 2010*, p. 361, p.345-348.

17. WIR 2005

18. WIR 2005, overview, p.XXVI-XXXII.

19. WIR 2005, p.166.

year, on average, between 2000 and 2010, versus 3.2 % on average, in G 7 markets. Raising the R&D intensity in the next decade to 2.5 % of GDP, which is a realistic aim of the 2020 Plan, would translate into tripling R&D spending to 300 billion $US.

The top 25 TNC's by reported R&D investment, collectively responsible for nearly 84 billion $US R&D investment in 2010, have a tendency to globalize their activities in research intensive industries such as pharmaceuticals and technology hardware. Pfizer, the world's second-leading corporate R&D investor (at 7.4 billion $US), has its own R&D center in Shanghai and research partnerships with leading Chinese universities. General Electric has had research facilities since 2000. Ten years later, 1,500 of its global 2,800 research staff are based in China. Philips has 1,800 research and development staff in China, 110 of them working on high-level research. Microsoft employs 3,750 full-time researchers and developers in China, over 300 coming from the US and Europe, and 7,000 outside the company, working on a contract basis. Ninety percent of its R&D activity is for global products, with only 5 to 10 percent for local products. Intel, which had established its China Research center in 1998, has announced new equity investments in clean technology and healthcare software in China. IBM launched the China Analytics Solutions Center in 2009, to support its expansion in the region, and Applied Materials opened the world's largest solar research center in Xian, China, in 2009. This tendency may accelerate in the next decade, as students of Chinese origin now receive 11 % of all US scientific and engineering doctoral degrees, with more than 4000 PhD's in 2007, twice as many as students from Indian origin, and as global R&D investment is shifting toward growth markets[20].

Returning members of the Chinese diaspora play a key role in these R&D centers where locally recruited researchers provide the main manpower. In Shanghai, over 353 TNC R&D centers were established by 2010[21]. Between 2004 and 2010, R&D related FDI stock raised from 4 billion $US to 12.8 billion $US, according to the Chinese Ministry of Commerce. R&D centers established by foreign affiliates, generally wholly owned by their parent company, are mainly focusing on adaptive innovations for the Chinese market, especially in the electronic and ICT industries, with Beijing and Shanghai as the main centers. But this stage can evolve into global innovative R&D in certain cases: since the 1990s China mobile telecommunications has become the world's largest, in terms of network capacity as well as number of subscribers. Many telecom equipment makers have invested in production facilities as well as in R&D. Motorola had set its first R&D center in 1990, it had 15 centers with 1 300 R&D employees in 2004. Nokia at the same date had five centers with 800 R&D personnel while Ericsson had 9 centers with 700 R&D personnel. Certain models of mobile phones for the Asia Pacific market or the world market, including for 3G technologies, have been developed both for the Chinese market and the world market, in the R&D centers of Nokia or Ericsson.

Although labor rates in engineering were about a fifth of those in the US or Europe, before the global crisis of 2008, they reached about 40 % in 2011, and might eventually become similar with the quick rise of the costs of living in Shanghai or Beijing, where most of the R&D centers are based. In this new environment, the balance between cost and performance of products and processes, what Eric Thun calls "frugal engineering", and the choice of the best Chinese suppliers in terms of costs and quality will certainly raise the local R&D competition, and adapt it to the constraints of emerging markets[22].

The 2020 Plan for S&T and the key role of state owned enterprises

The current policy has been established during the last science conference, which took place in 2005, and issued a Medium and Long Term Plan for S&T for the period 2006-2020, with the following objectives: increasing R&D intensity to 2% of GDP in 2010 and to 2.5% in 2020; S&T contribution to 60% of growth; dependence on foreign technology reduced to 30%; and position

20. Douglas Gilman, The new geography of global innovation , Global Markets Institute, September 20, 2010, Goldman Sachs; Andrew Moody, "Research in motion : Multinationals moving R&D centers to China as the country aims to become an innovation nation", *China Daily, European Weekly*, November 11-17, 2011, p.1, 5-6.

21. WIR 2005, p.185, p.142. *China Daily, European Weekly*, November 11-17, 2011, p.1.

22. Eric Thun, Said Business School, Oxford University, "Shaping the new economy: R&D centers in China provide an opportunity for companies to re-think design, innovation", *China Daily European Weekly*, Nov-11-17, 2011, p.7.

China as number 5 for patents and citations of publications worldwide.

To reach these objectives, the country must give priority to technological development in 11 key sectors (energy, water resources, environmental protection, ICT, nanosciences and nanotechnology, health, food agriculture and fisheries, biotechnology, aeronautics, aerospace, new materials, security and defense), as well as improve the national Intellectual Property System and its enforcement, and encourage enterprises to play the key role in innovation through state projects, tax incentives and other financial support[23]. Sixteen mega projects were already carried out during the 11th 5-year plan (2006-2010) on key sectors. In the 12th 5-year plan (2011-2015), the emphasis is augmented on life sciences, and in particular drug discovery, and infectious diseases, which have strong societal and economical potential, and where China needs upgrade.

In addition to S&T programs which play a signaling role to enterprises in terms of priority directions, in S&T intensive sectors such as IT, new materials, new energy, biotech and environmental technology, the government favors S&T Industrial Parks (STIP) and Technology Business Incubators (TBI) to promote academia-industry partnerships, through both commercialization and internationalization of R&D[24]. Zhongguancun Science Park, in the Northwest of Beijing Haidian district, is the largest science park, home to 40 universities and 130 research institutes. By 2004, it had attracted 41 foreign invested R&D centers, 60 % of them in the ICT industry, by leading TNC's such as Hewlett-Packard, IBM, Motorola, Nokia, Nortel, Oracle, Samsung, Siemens, Sony, Sun Microsystems and Toshiba, to name a few.

This 2020 Plan represents a radical change from the previous policy as it aims to decrease the country's reliance on foreign technology to 30 % or below, and to develop « indigenous innovation ». The technology development is now based on an « import-assimilate and re-innovate » model. This is a far cry from the previous division of labor as noticed by the Executive Vice-President of IBM for innovation and technology, Nicholas M. Donofrio, who declared in 2005: « the global innovation-commoditization cycle has never been more pronounced than it is today, and it forces distinct choices. Winners can be the innovators –those with the capacity to invest, manage and leverage the creation of intellectual capital- or the commodity players, who differentiate through low prices, economies of scale and efficient distribution of other parties' intellectual capital »[25]. The previous low-skilled and low-paid worker thus reincarnates into an engineer, who re-innovates through the re-appropriation of intellectual capital. A clear illustration of the process of climbing up the value chain.

A striking feature of China's innovation system is the expanded role of enterprises, and its orientation toward development activities. Government research institutes, which are supposed to carry on basic as well as applied research, represent less than 20 % of R&D expenditure, and 18 % of R&D personnel (2006). In 2005, nearly 95 % of their expenditure was concentrated in the field of natural sciences and high-tech related fields. The higher education sector, where applied research is predominant, concentrates less than 10 % of R&D expenditures, and 16 % of R&D personnel, mainly based in the top 50 universities (66 % of expenditures) on a few key disciplines in natural sciences and engineering. The business sector provides a large share of its funding, and plays an important role in research-industry linkage.

The bulk of R&D, 71 %, is almost self-financed by the business sector, mainly the State-owned and State holding enterprises which occupy nearly 66 % of R&D personnel on experimental development in diverse industrial sectors (communication, computer, electronic equipment, instruments, chemicals etc.). As in the higher education sector, R&D activities are often carried out on a project basis. The share of basic and applied research expenditures over total R&D spending went down to 17 % in 2010, compared to the OECD countries with an average level of 50 %. Basic research represents less than 6 % of total R&D spending, with a slight decline in recent years, to be compared with an average of 20 % in OECD countries. The present step by step catching up strategy is clearly focused on development (83 % of R&D) in order to reduce the

23. *National Guidelines for the Medium and Long-term Plan for Science and Technology Development (2006-2020)*

24. In 2006, STIPs accounted 45 828 companies, with 5.7 million employment, mainly shareholding (23 244) with 2.7 million employees, but also collectively owned, State-Owned or foreign owned enterprises: see Martin Schaaper, (2009), p. 31.

25. Fabre, G., (2008), p. 305.

technological dependency to OECD countries and to compete with them on innovative products. The new technology intensive growth aims at a higher economic efficiency, by lower energy consumption, lesser pollution and a better use of human resources. In order to bridge the technology gap with OECD countries, State-owned enterprises, the country's 80 to 100 big corporations were chosen as the foundations of the country's micro-economy as well as the key components of the indigenous innovation policy.

As the 2020 Plan aims at indigenous innovation and the reduction of the dependency on foreign technology, it is legitimate to ask if the internationalization of R&D, as the next stage of outsourcing, will turn into a win-win situation. Large public investment toward important areas of research has put China on the map in genomics, nanotechnology, clean energy, space science, supercomputing and defense technology. Apart from these dramatic successes in strategic sectors of R&D, China's relies on the size of its potential consumption market, the scale of its public investment and procurement, the competitiveness of its labor force and the dynamics of its R&D and innovation policy, to ask for technology transfer in exchange for market access[26].

Some oppose strong arguments against such deals. As high-tech sectors, like alternative energy are supposed to revive economic growth in OECD countries, Gary P. Pisano, from the Harvard Business School, underlines the fact that the US « has lost or is in the process of losing the ability to manufacture many of the cutting-edge products it invented. These include the batteries that power electric and hybrid cars, light-emitting diodes (LEDs) for the next generation of energy-efficient lighting, critical components of solar panels, advanced displays for mobile phones and new consumer electronics products like Amazon's Kindle e-reader, and many of the carbon-fiber components for Boeing's new 787 Dreamliner ». He opposes the idea of divisibility of R&D and manufacturing which has prevailed in the last 25 years. Innovation needs a two-way feedback, from R&D to production but also from production to R&D, as « the act of production creates knowledge about the process and the product design ». There are of course exceptions where R&D and manufacturing are separable, but in the vast majority of high-tech products, « when manufacturing capabilities migrate from a country, design and R&D capabilities eventually follow »[27].

In fact, for foreign companies, producing in China is the only way to get access to the market. In 2007, foreign capital firms were responsible for about 25 % of total industrial production for domestic use (Gaulier, G., Lemoine, F., Deniz Ünal, D., 2011). But in the same time, as Nirmal Chandra underlines, citing the Eleventh Five Year Plan for Use of Foreign Investment: China will « encourage foreign enterprises – especially large-scale multinationals – to transfer the processing and manufacturing processes with higher technology levels and higher added-value and research and development organizations to China…to develop a technology spillover effect, and strengthen the independent innovation ability of Chinese enterprises…. The overall strategic objective of use of foreign investment in China is to … change the (previous) emphasis from making up the shortage of capital and foreign exchange to introducing advanced technology » (Chandra, N. 2012).

In the new landscape of indigenous innovation, quite different from the previous one, the question for most foreign capital corporations is less to control « the stealing of IPR » by counterfeiters, than to organize the extent of their technology transfer while keeping their core technology. There is no way to capture the real dimensions of these transfers, since the Chinese government does not publish any balance of payments for technology. Some studies conclude that as the skill intensity of exports increases, the percentage of the value of the final product that derives from imported components rises sharply, as for electronic devices (85.2 %), telecommunication equipment (91.6 %) and computers (96.1 %). China would have remained « a low value-added assembler of more sophisticated inputs imported from abroad, a 'workbench' economy » (Moran, T.H. 2011). The dominance of foreign firms and the large share of imported materials in processing trade « raise the question whether China's high-tech industries are really high-tech and whether the high-tech industries in China are really Chinese » (Schaaper, M., 2009, p.62). These

26. Gordon, K., Lyon, S., Paisley, E., Pool, S., (2011).

27. Gary M. Pisano, « The U.S. is Outsourcing Away Its Competitive Edge », *Harvard Business Review,* October 1, 2009. http://blogs.harvardbusiness.org/hbr/restoring-american-competitiveness/ 2009/10/the-us-is-outsourcing-away-its.html

conclusions may be excessive, as noted by Nirmal Chandra. Since the threshold of foreign equity is only 10 %, many foreign enterprises may be controlled by State-owned enterprises, and these figures do not reveal the potential of China's domestic firms, as China has become the regional hub for the production of high-tech goods. After all, Korea's Samsung and LG began assembling electronic components as subcontractors of US majors, before rising to the status of global leaders (Chandra, N., 2012).

According to the first national survey of firm innovation conducted by the State Statistical Bureau in 2007, State-owned and state-holding enterprises are the main actors of innovation in China, since they account for 81 % of total business R&D in 2006, mainly in pharmaceuticals, instrument and office machines, tobacco, communication and electronic equipment, and special measuring equipment[28]. SOE's have been the core of China's « going global strategy » since its launching in 2000, and they play a dominant role, after their restructuration in the 1990s in capital intensive and strategic sectors such as petroleum, coking, nuclear fuel, raw chemical material, transport equipment, mining and electric and heat power, gas and water. Their profits have increased nearly four-fold between 2000 and 2009 and in 2007, they represented 83 % of the stock market capitalization[29].

Catching-up in high potential sectors

High speed trains

The high-speed (HS) railway program is a very interesting example of China's indigenous innovation policy led by SOE's. The first HS railway, the Beijing-Tianjin intercity line, covering the 120 km distance in 30 minutes, was opened for service on August 1, 2008. With the global financial crisis of 2008, China's leaders turned the project into a part of the economic stimulus package, speeding construction, including moving up the completion of the 33 billion $US Beijing-Shanghai line in a year. By the end of 2009, total HS operating length had reached 6,552 km, and the Ministry of Railway had another additional 10,000 km of HS rails under construction [30].

The People's Daily presented the development of China's high-speed railways as an example of domestic innovation after incorporating advanced technology from developed nations[31]. In 2004 the Railway Ministry signed deals to buy trains from Kawasaki Heavy Industry (KHI), which transferred production facilities and the know-how for its 200 km/h bullet train for 760 million $US. Alstom and Bombardier signed similar deals for their first or second generation bullet trains rolling at 200-250 km/h, and in 2005, Siemens transferred technologies for a 300 km/h HS train. Engineers trained by Kawasaki in Japan later helped to build the Qingdao factory of China's South Locomotive and Rolling Stock Industry Corp. or CSR, which now produces about 200 train sets a year, some of them rolling at 300 km/h. A CSR senior engineer declared: « Real innovation is rare. We attained our achievements in high-speed train technology by standing on the shoulders of past pioneers »[32].

While its competitors from Bombardier, Siemens and Alstom preferred to keep silent, in a market which is expected to account for more than half of global railway spending, until 2020, according to World Bank estimates, Kawasaki openly denied China's claim that it had created its own technology. According to a public communiqué of the firm, the CRH2 bullet train in operation today is practically the same as the original Japanese one. KHI hopes to settle the issue through commercial talks, but contests the IPR of its Chinese partner to export the technology[33]. The Chinese Ministry of Railways has organized a team of lawyers to examine how vulnerable state companies would be to IP lawsuits, in outside markets. But some foreign companies have already accepted to form partnerships with the Chinese groups bidding on HS projects all over the world. In 2010 for instance, Siemens dropped its own bid to build and operate a line in Saudi Arabia so it could join a Chinese consortium.

If competitors mostly believe that China has in a way « metabolized » the imported technology, the Chinese however have been mastering the

28. Schaaper, M. (2009), p.56 ; Wu YanRui, (2010) and (2011), p.7-8.

29. Lee, J., (2009); *The Economist*, 3/09/2011.

30. Xinhua, 3/07/2010.

31. Li Hujun, *Caixing*, 23/06/2011.

32. Norihiko Shorozu, *Wall Street Journal*, 22/11/2010.

33. Norihiko Shirozu, *Wall Street Journal*, 22/11/2010.

competition between different foreign groups in order to obtain a larger share of technology than it was publicly admitted. Foreign industry executives estimate than around 90 % of the HS technology used in China derives from partnerships or equipment developed by foreign companies, while for such programs the Chinese government applies the rule of a 30 % dependency, which means officially that 70 % of the (digested) technology is Chinese.[34]

Although tarnished by the dismissal and arrest for corruption of the Chinese Ministry of Railway, Liu Zhijun, in February 2011, and later by the tragic collusion of two trains in Wenzhou which caused 40 deaths and hundreds of casualties (July 2011), the Chinese HS train program, with all the excesses of a « top-down » strategy, illustrates the huge amount of investments in « indigenous innovation », which has been allocated by the stimulus package following the global crisis of 2008. The rhythm of the indigenous innovation policy has clearly accelerated since 2008, reflecting the evolution of the leadership's choices in favor of strategic sectors such as aircraft and spacecraft (where R&D represents 15.39 % of the added value), electronic and communications equipment (where its share is 6.78 %), medical equipment and meters manufacturing (6.28 %), pharmaceuticals (4.66 %), computers and offices equipment (3.87 %).[35]

Aeronautics

If we turn to the aircraft and Aerospace industry, which is the top priority of China's innovation policy, it is striking to observe the asymmetry between the Chinese government's strategic will and the relative passivity of the US and European governments which tend to relegate policy developments in this area to private parties, or even to follow their initiatives. In May 2008, China announced that it had " established a homegrown company to make passenger jumbo jets… to become less dependent on Boeing and Airbus". A new consortium is formed, the China Commercial Aircraft Company, with a capitalization of 2.72 billions $US, and the participation of the two leading aircraft companies in China, China Aviation Industry Corporation I, (AVIC I), and China Aviation Industry Corporation II, (AVIC II), which have about 491,000 employees with their subsidiaries. China already has the muscles for such an ambition with six companies devoted to « air frame assembly », eight « engine companies », 28 entities involved with components, and 20 research institutes[36].

The same year, China signs an agreement with Airbus to build a plant in Tianjin, which is now assembling with success 10 % of the A 320 production. The European aircraft manufacturer has planed to deliver more than 110 A 320 planes to China in 2011, accounting for one fifth of the company's deliveries worldwide, and has sold to China Southern Airline his first out of five superjumbo A 380 aircraft. Airbus remains optimistic about the perspectives of the Chinese market, since it is the second in the world and should be the first at the 2020 horizon, according to its projections[37]. In the interval, in April 2009, a first design of the planned Chinese Jumbo jet, the new « C 919 » was released, with the first test flight announced for 2014 and the first delivery for 2016. The country would be capable to produce 150 domestically made jumbo planes each year. « Although Western companies are seeking to become suppliers to the program, even if they are successful, question remains regarding how much of those contracts will be supported by production outside China » asked an aircraft expert[38].

Two agreements recently signed provide an answer, and suggest that the same digestive proportion as for the HS trains, 70 % of « indigenous innovation » and 30 % of foreign technology dependence, will apply in the aircraft industry. In September 2011, AVIC, the supplier of the C 919 project, signed a 50/50 joint venture with General Electric, to develop a new generation of its avionic operating system (the « brains » guiding navigation, communication, and other operations on an airplane), which is already on board the Boeing 787[39]. The same month the French government created, after « Centrale Beijing », one of his best engineering university, and the «Sino-French Institute of nuclear energy », the

34. Jamil Anderlini, *Financial Times*, 23/10/2010.

35. Wu, Yan Rui, (2011).

36. USCC.gov, U.S-China Economic and Security Review Commission, May 10, 2010, Testimony of Owen E.Herrnst Adt, Director of Trade and Globalisation, International Association of Machinist and Aerospace Workers, « China's Emergent Military Aerospace and Commercial Aviation Capabilities », hereafter*:* Owen E.Herrnst Adt.

37. Xinhua, 15/10/2011.

38. Owen E. Herrnst Adt, Testimony, *op.cit.*

39. John Bussey, China Venture is good for GE but is it good for the U.S? *The Wall Street Journal*, 30/09/2011.

« Sino-European Institute of Aviation Engineering » in Tianjin, a consortium of the Ecole Nationale de l'Aviation Civile (ENAC), the Institut Superieur de l'Aéronautique et de l'Espace (ISAE) and of the Ecole Nationale Supérieure d'Aéronautique et d'Aérotechnique (ENSMA), which will form a first promotion of 100 engineers in 2013. French officials tend to insist on the francophone curriculum[40], while the Chinese authorities are more motivated by other perspectives. The C 919, if successful, would be the first of the new models of the Chinese aircraft industry, which may compete with Boeing and Airbus in the market for large commercial aircrafts. Here again, the two companies believe that their technological advance and manufacturing capacities may keep them ahead of innovation.

Clean energy

The two examples of the HS train program and the C 919 project are clear illustrations of the Chinese art of creating competition between TNC's while restricting their share of big public procurement contracts through indigenous innovation as well as by organizing bidding processes in favor of Chinese SOE's. Clean energy is another priority of the 2020 Plan, not only for obvious domestic reasons, (China being the largest issuer of CO_2) but also because by 2020, it will be one of the world's biggest industries, estimated at 2.3 trillion $US[41]. China is the first country in the world in terms of renewable electricity capacity, with 16 % of its electricity from hydropower and wind power at the end of 2009. The wind power sector has been growing rapidly through the Kyoto Protocol clean development mechanism (CDM), which allowed advanced countries to offset their emissions at home by investing in clean energy projects and transferring technology in developing countries such as China. A surge of investment followed in the very attractive domestic market, to the extent that major wind manufacturers rapidly grew from a mere five or six to 70 in 2008, leading the Chinese government to revise its 2007 national target of respectively 10 GW and 30 GW of installed wind capacity for 2010 and 2020, as 20 GW were already installed at the end of 2009! But here again, the authorities imposed a 70 % local requirement for wind power equipment, all along this surge, according to the standard of « indigenous innovation ». The result was that the share of foreign suppliers in this fast growing market dropped from 75 % in 2004 to 13,8 % in 2009. This requirement has finally been dropped following the complaints of foreign manufacturers at the beginning of 2010, but it has served its purpose, since there are now concerns for wind manufacturing overcapacities among Chinese wind firms and a race for exports. Today, only domestic or JV firms with at least 50 % Chinese ownership can operate or develop offshore wind farms. The American Chamber of Commerce and the European Chamber of Commerce in China have openly complained since 2010 about these forests of moving rules, which have the purpose to restrict access to the local market, in a lot of sectors[42].

As for solar energy, China has been the leading manufacturer of photovoltaic panels, behind Germany, with 30 % of the world production mainly for exports. At the end of 2009, the country had just 0.3 megawatts of installed power capacity, but two major policies were adopted in the same year to stimulate the domestic market, and in July 2011, the release of a national photovoltaic feed-in-tariff policy has resulted in a surge of non-residential projects. In 2011, the PV market in China will exceed 1.6 GW, a 230 % growth over 2010 [43]. Applied Materials, one of the world's leading suppliers of the equipment to make semiconductors, solar-panels and flat–panel displays has based in Xi'an, northern China, the only research center that can fit an entire solar panel assembly line, to make advanced research on solar manufacturing. The choice of Xi'an is motivated by an attractive discount on a 75 year land-lease, five-years subsidies covering a quarter of the lab's operating costs, and the supply of low-cost engineers with master's degree who can be hired for 730 $US per month. The development phase of the global research will be done in Xi'an, with 360 employee-operation, while the company has resolved to reduce employment from 10 to 12 %,

40. *Les Echos*, 27/09/2011.

41. Gordon, K., Wong, J.L., McLain, J.T., (2010) p.1.

42. Gordon, K. (2011) p.29-30; Mc Gregor, J. (2011) p.33; James T. Areddy, U.S. firms complain of China's heavy hand, *The Wall Street Journal*, January 19, 2011. European Chamber of Commerce (2010), European Business in China, *Position Paper*, 2010-2011, p.353-354. http://www.europeanchamber.com.cn/view/static/?sid=7479

43. Gordon, K. (2011). p.28-29 ; http://www.solarbuzz.com, October 10, 2011 : China's feed-in tariff policy stimulates 14 GW photovoltaic project pipeline .

or 1300 to 1500 jobs, in the US and Europe[44]. This recent example shows how the internationalization of R&D may stimulate a country's competition.

Information technology

The strong focus in Western media on the censorship imposed on the Internet has often led to underestimate the strategy of China towards IT and the information society, and overestimate the importance of the control of the content. The reality is rather different. John Chambers, the CEO of Cisco Systems, a front ranking IT firm making network technologies, was reported saying as early as 2003: « China will become the IT center of the world. What we're trying to do is to outline an entire strategy of becoming a Chinese company »[45].

IT is a global worldwide priority, for which China enjoys a predominant position. China has the largest connected population: half a billion people on line, and close to a billion with mobile phones, with a strong appetence for new technologies. Some of its corporations in IT are now among the very first ones in the world: telecom operators as well as equipment corporations, and its research is becoming visible.

IT is the top priority of most of the Chinese research programs, with for instance more than 20% of the spending of the 863 program for high-tech R&D in 2008, and three out of the 16 priorities of the 2020 Plan. As a result, the number of publications in information technology has increased drastically in recent years. « In 2009, for the first time, Chinese researchers published more papers in information technology than those in the US, with both countries churning out more than 100,000 info-tech publications »[46] according to a survey of SciVal Analytics, a division of Elsevier for Forbes. With a growth of 22% since 2005, China has tripled its number of articles. The impact of the Chinese publications still lags behind at 0.6 of the world average, versus 1.6 for the US, but it has been continuously increasing. In some fields its achievements have gained great pride.

44. Keith Bradsher, China drawing high-tech research from US, *The New York Times*, 17/03/2010.

45. Chandra, N. (2012)

46. http://www.forbes.com/sites/matthewherper/2011/05/25/the-most-innovative-countries-in-information-technology/

China pursues a very aggressive strategy in supercomputing. It hits the headlines in November 2010, when it became host of the world fastest computer, with its supercomputer Tianhe-1A, made by the National University of Defense for the National Super Computing Center in Tianjin. Tianhe-1A reached 2566 Tflops (trillions operations per seconds), twice as much as the fastest American supercomputer, the Cray at Oak Ridge National Laboratory, which reached 1759 Tflops[47]. The third supercomputer in the Top500 list of supercomputers, the Nebulae, also Chinese, was made by Dawning, for the National Supercomputing Center in Shenzhen.

While back in 2001, China had not a single computer on the Top500 list; it had 61 a decade later, and holds now the second position for the supercomputing power, after the US, which have 255 sites, and ahead of Germany, the UK, Japan and France. This boosted the efforts of Japan to come back in the race, and take over the first position in June 2011.

The chips used in the Chinese supercomputers are Intel CPUs, and graphical chips, Nvidia GPUs, thus still American technology, but China is working also on new generations of supercomputer based on Chinese chips only. The supercomputer Dawning 6000 relies on the Chinese chip Godson 3B developed by the Chinese Academy of Sciences, provides 300 Tflops, and is claimed to be more energy efficient. China has invested less though in the software issues raised by its supercomputers, whose capacity is currently under used.

The Telecom industry is extremely successful, with about 900 million mobile users at the end of 2011, three big operators, all state owned, China Telecom, China Unicom, and China Mobile, and a very active sector of telecom equipment corporations, dominated by Huawei and ZTE. Huawei is now the second supplier of mobile telecom infrastructures in the world after Erikson. All these companies have developed important R&D labs. The most impressive is Huawei, which has developed a large worldwide network of twenty laboratories, with its main campus in Shenzhen, and labs in the USA, Russia, India, Sweden, France, etc. Huawei, with about half of its workforce (50,000 employees) devoted to research,

47. The list of the top 500 supercomputers is published twice a year on www.top500.org.

spent 16 billions Yuan (2.5 billion $US) for R&D in 2010, with an annual increase of 24%. Some products raised controversies, first on IPR issues, for instance with Cisco on technologies for router and switches, as well as more generally on security issues.

The Chinese Internet is the largest in the world with half a billion people online. The Chinese language is also the second language with 509 million Chinese-speaking people online in 2010, almost as many as the 565 million online English speakers[48], but with a smaller penetration rate, 37% versus 43%, which will undoubtedly lead the Chinese to become the first linguistic community online.

China has developed a large industry on the net, with essentially all the usual services offered by mostly American companies, such as online search engines, social networks, news, business, instant messaging, etc. Chinese companies have taken advantage in their development of the difficulties to access their foreign counterparts from Mainland China. Among the top 20 sites in the world, published by Alexa[49], a subsidiary of Amazon, China counts 4 sites, while the others all belong to US corporations. It is worth mentioning them: Baidu, the Chinese search engine, also operating in Japan; QQ, owned by Tencent, which offers mail, instant messaging, games, etc.; Taobao, an e-commerce platform; and finally Sina, which provides news as well as other services. All of them are widely used in Hong Kong and Taiwan of course, but also in South Korea, as well as in Russia for e-commerce on Taobao. It is worth noting that China is the only country that succeeded in developing such a powerful industry not relying on the services offered by US corporations.

The telecom equipment industry is also of strategic interest, not only for its important business perspectives, but also for security reasons. Huawei is an excellent illustration of the potential of Chinese SOEs, which managed to challenge well established enterprises on the global market, such as Alcatel-Lucent for instance, and compete with them on research issues. China has developed a very comprehensive and strategic vision for the telecoms, from the equipment industry and the operators to the content industries. This has raised some worries in the US, which have a strong domination of the Internet, essentially only challenged by China.

CONCLUSION

Until recently, China's R&D and innovation policy has been mainly analyzed in comparison with that of Japan and the four dragons, in terms of "climbing up the value chain". This type of analysis underestimates the impact of the scale of China, with not only the new "scientific and engineering demography" created by the "Real leap forward" of the 2000s but also the manufacturing capacity which has already bypassed that of the U.S, the growing internal market, and the rising presence of Chinese TNC's in emerging markets.

If we add to these factors national sovereignty, which plays a key role in the sensitive IT sector, as well as in defense related R&D, it is clear that China's R&D and innovation strategy, presented in 2006 as the second stage of the opening and reform policy, is slowly changing the global landscape of technology, and moving the frontiers. Although China's wish to reduce its technology dependency is perfectly legitimate, the "indigenous innovation" set in the 2020 Plan is viewed by many international technology companies as a "blueprint for technology theft on a scale the world has never seen before"… Some analysts remain pessimistic as regards the consequences of this new "techno-nationalism" coupled with a reduction of market access: "As the belief by foreign companies that large financial investments, the sharing of expertise and significant technology transfers would lead to an ever opening China market is being replaced by boardroom banter that win-win in China means China wins twice", we are heading toward "contentious trade disputes and inflamed political rhetoric on both sides"[50].

"Innovation with Chinese characteristics" strangely recalls the banner of "Marxism with Chinese characteristics", which opened the way to the subsequent Maoist's drifts[51]. But today's stakes, by shifting to science, at a time when China has become the leading manufacturing country in the world, and may become a leading country in strategic sectors such as IT, are of another scale. It remains to be seen if this "top-down" model

48. http://www.internetworldstats.com/stats7.htm

49. http://www.alexa.com/topsites

50. Mac Gregor, J. (2011), p.4 and 6.

51. Fabre, G., (1990), p. 49-50.

of R&D and innovation, strongly criticized by prominent Chinese scientists, from inside and outside China, for giving bureaucrats too much power on scientists[52], does not aim at using R&D for the sole benefit of a political power. The derailment of the HS train program, following a fatal HS train crash in July 2011 illustrates the limits of this new "techno-nationalism".

However, it would be a mistake to focus on "indigenous innovation" without considering the whole picture of the R&D landscape, which is much more open that it seems at first sight. Although there are conflicting views in some strategic sectors, such as aeronautics, clean energy vehicles, HS trains, where "the Chinese government exerts leverage where it can and foreign firms do what they can to limit the loss of their core technologies", R&D is not reducible to this "cat and mouse game"[53]. In other sectors such as chemistry, life sciences, IT, and nanotechnology, things appear much more open, and the constant flow of foreign researchers, now facilitated with the Chinese green card, or researchers of Chinese origin from the U.S and Europe, to China and back, may certainly create a new climate of hybrid R&D and innovation, such as the one which already exists with other East Asian countries.

Some TNC's executives are convinced that China is the new frontier of innovation. Andrew Lewis, the CEO of Dow chemicals is confident that "innovation has followed manufacturing to China"… "Over time, when companies decide where to build R&D facilities, it will make more and more sense to do things like product support, upgrades and next generation design in the same place where the product is made"…" "That is one reason why Dow has 500 Chinese scientists working in China, earning incredibly good money, and who are already generating more patent per scientist than our other locations"[54]. The Chinese president's speech at the APEC summit in Hawaii illustrates the strong political will of the leadership in this regard: "China will work hard to turn itself into an innovation driven country, bring in high caliber and innovation-minded professionals from overseas and realize the transformation of *Made in China* to *Created by China*"[55]. But it is still unclear whether these two approaches are compatible on the long term. It will depend not only on the pragmatism of the Chinese direction but also on the capacity of non-Chinese to adapt to China, to its culture, to its rules, and interact in a constructive way with a new and considerable actor, which is definitely changing the R&D landscape.

52. *Nature Magazine*, special issue, Fall 2004.

53. Eric Thun, *op. cit.* p.7.

54. John Bussey, Does history says China wins? *Wall Street Journal*, November 4, 2011.

55. Xinhua Agency, 12/11/2011.

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