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China as a S&T Superpower

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Abstract

With the rapid growth of Chinese investments in science and technology, and the expansion of outputs in terms of scientific articles, patents, and technological capabilities, some observers have predicted that China is on its way to becoming a technological superpower. This prediction is naturally based on the rapid developments in the input of R&D investment and output of scientific publications and patents that have taken place in China during the recent decades. But what does the concept of a scientific and technological superpower imply? In this paper, I shall discuss several interpretations of the concept the concept of superpower and provide a preliminary assessment of key trends that have been seen as the promise of China's emerging status. In conclusion, I propose that if, indeed, China is becoming a S&T superpower, I hope that it will become a different type of superpower.

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China as a Science and Technology Superpower: An Assessment

The economic growth experienced by China since the introduction of reforms in the 1980s has been seen by several observers as a sign that the country is about to reach the status of an advanced industrialized country and a could become the dominating World power of the 21st Century (Jacques, 2009). Politically, China's membership of a select group of nations in the UN Security Council with veto rights assures a position as a major power, while the possession of military capabilities as a nuclear power with long-range missiles assures the country a position as a powerful nation in regional and international arenas. In terms of technology, the achievements of China's space program such as manned space flight and the docking of Shenzhou-8 capsule with Tiangong-1, and the prominence of the Tianhe-2 supercomputer as the World's fastest computer, have justified considerable Chinese national pride.

The achievements in the broader area of science, technology and innovation during recent decades have also been impressive. Chinese investments in research and development (R&D) have been raised substantially, and increasingly involve funding from Chinese firms in addition to expanding public funding. Thus, the significant indicator of investment in R&D as a ratio of GDP has tripled from 0.6% in 1996 to 1.8% in 2010. Chinese firms accounted for 42.9% of the country's R&D spending in 1997, and this figure rose to 60.3% in 2000 and reached 73.4% in 2010 – a ratio equivalent to those of advanced industrialized countries such as Japan and the US (Wu, 2012). In terms of S&T output, there are also statistics that show the extent to which China has become a major producer of patent applications among the top 15 patent offices in the world, with Chinese patent applications being 19.8% share of total in

2010, occupying second place after the United States that had 24% share of total in 2010 (WIPO, 2012, p. 17). For scientific publications, China again occupies a second place, with 836,255 papers from the PRC and 3,049,662 from the United States in 2011 for the time period 2001-August 31, 2011 (Thomson Reuters, n.d.). Moreover, Chinese firms ZTE and Huawei now belong to the top five companies that have applied for international patents.

These achievements – and many other successes of scientific or technological excellence – have prompted observers to envision that China will become a S&T superpower in the foreseeable future. This projection has been assessed in several books and reports (e.g., Sigurdson, 2005; Wilsdon and Keeley, 2007), as well as in various articles (e.g., Miller, 2005) and blogs (e.g., Segal, 2013). While Sigurdson (2005) provides a cautious, but optimistic perspective of the potential for China to reach a technological superpower status during the 21st Century – possibly even before 2020 – most other scholars have argued that there is little probability that this scenario would materialize in the coming decades. For example, Segal (2013) argues that the US is still the world leader in science and technology, but Chinese capabilities are developing rapidly, being on track to pass the US in terms of spending on research and development in 10 year. At the same time, he notes that this development poses serious challenges to the US in areas such as intellectual property protection, cyber and industrial espionage, and the "predatory" policies of indigenous innovation. Other observers are less persuaded that China represents a direct threat to the US, especially if the country's leadership is actually emulating many US policies and institutions, or "playing our game" as argued by Steinfeld (2009).

A cautious conclusion emerges from one of the studies that explicitly sought to assess the key trends in China's development of science and technology:

> What is often lost in the welter of statistics about R&D investment and engineering graduates is a sense of the raw power of the changes that are under way, and the dizzying potential for Chinese science and innovation to head in new and surprising directions. We cannot say with any certainty where things may lead, but such large and sustained investment in innovation, within a system that for a long time suppressed such impulses, seems likely to produce a growing number of extraordinary achievements at the frontiers of science over the next ten or 15 years. (Wilsdon and Keeley, 2007, p. 60)

As important as it is to discuss and evaluate the latest statistics on China's S&T system, it is necessary to position any assessment of current and future trends in the context of what it actually means to be a superpower, and understand whether China is likely to represent something altogether different.

What is a S&T Superpower?

In order to discuss the potential status of China as a S&T superpower, it is of course necessary to attain a better understanding of the concept of "superpower" and, in particular, how ideas associated with "superpower" may be applied or modified to form a distinct concept of "S&T superpower".

The Definition of Superpower

The Oxford Dictionary probably has the simplest definition of superpower as "a very powerful and influential nation." A slightly more elaborate definition as "great power plus great mobility of power" was coined by William T.R. Fox when he first introduced the concept in The Super-Powers: The United States, Britain, and the Soviet Union – Their Responsibility for Peace (Fox, 1944). Another scholar who elaborated on the definition and explored the historical background of the emergence of powerful nations was Dukes (2000), who argued that “A ‘superpower’ must be able to conduct a global strategy including the possibility of destroying the world; to command vast economic potential and influence; and to present a universal ideology.” These scholars underscored the distinction between great powers and superpowers, emphasizing the importance of global reach or global dominance (or hegemony) for the definition of a superpower. Basically, for more than three millennia great powers have fought for supremacy in what was at the time considered “the world”: for example, the Roman Empire dominated much of Europe and the Middle East, exerting its power militarily, politically and culturally in ways that left a lasting legacy; the Chinese empire has, during long periods in history, held a similar dominating position in the realm of tianxia “all under heaven”; the Mongol empire extended its military and economic command to most of Asia and the Middle East, but for various reasons failed to subjugate Western Europe and Japan. In recent history, the British Empire have been considered a superpower (Fox, 1944), but since World War II, most observers have agreed to only designate the United States of America and the Soviet Union as superpowers.

One of the political scientists that have attempted to provide a more sophisticated theoretical concept of what creates a superpower is Zbigniew Brzezinski, who presented four dimensions of the criteria that in combination would constitute essential components of a “global superpower” status:

> In brief, America stands supreme in the four decisive domains of global power, militarily, it has an unmatched global reach; economically, it remains the main locomotive of global growth, even if challenged in some aspects by Japan and Germany (neither of which enjoys the other attributes of global might); technologically, it retains the overall lead in the cutting-edge areas of innovation; and culturally, despite some crassness, it enjoys an appeal that is unrivaled, especially among the world's youth—all of which gives the United

> States a political clout that no other state comes close to matching. It is the combination of all four that makes America the only comprehensive global superpower. (Brzezinski 1998, p. 24)

These four dimensions were also employed as analytical categories to measure the extent to which China could attain superpower status in Lyman Miller's essay "China an Emerging Superpower" (Miller, 2005), leading to the conclusion that China was establishing itself as a great power, but would not be likely to emerge as a superpower soon.

Proposed Definition of a S&T Superpower

It is tempting to conveniently use the same four categories to analyze the status of China as a (emerging) superpower. In that case, the definitions of the four domains need to be tweaked, since it is also possible to argue that the only category relevant for an examination is the aspect of technology and innovation – while the other categories are irrelevant or merely derivatives of technological strength. Using this approach, one possible way to define the status of a S&T superpower is according to relative strengths and weaknesses in the following four domains:

A. Militarily: The extent to which scientific results and domestic technological innovation contributes to the extension of advanced technological capabilities in warfare. For a superpower, these capabilities require sophisticated systems for regional or global reach of major weapons systems and strike capability.
B. Economically: The extent of the development of global economic competitiveness that is based on scientific and technology advance. For a superpower, this dynamic of a world-leading competitiveness should be pervasive in major sectors of the economy, including agriculture, industry and services.
C. Technologically: The requirement of a superpower is to maintain an overall lead in all cutting-edge areas of innovation, underpinned by a powerful S&T system

D. Culturally: The appeal of the S&T system to talented people world-wide, and the attraction of the institutions of scientific research and technological development to enterprising youth.

While these dimensions of a S&T superpower make sense when comparing various countries against each other, and especially if S&T is seen as a means to extend political and military power globally, it is in my view somewhat deficient when evaluating whether a country (or a region, for that matter) is really dominating and globally influential in science and technology. In other words, the most important question for me should not be whether a country is technologically equipped to bully neighbors and communities far away, but whether the country is truly world-leading in pushing the frontiers of scientific research and technological development forward.

Therefore, I would suggest that an alternative concept of what constitutes a S&T superpower could include the following dimensions:

A. Excellence and leading position in original frontier research: The extent to which scientific research is generating new and original discoveries that are creating substantial leaps forward in major disciplines. For a superpower, these capabilities would often reside in major universities and national research organizations, but they would increasingly also be spearheading efforts of international research networks. One significant indicator of this dimension would be a number of Nobel Prize laureates whose work was completed in the research system of the S&T superpower.

B. Global center of attraction for talented researchers and entrepreneurs, contributing to frontier technological innovation in the global economy. For a S&T superpower, centers of excellence will constitute key nodes in networks of extended global reach for the mobility of researchers and innovative entrepreneurs that aids the diffusion of new technology across the world. Some of these centers of excellence will be public institutions, such as universities, but many will be private, such as high technology ventures or the ubiquitous transnational corporations that are increasingly global R&D actors.

C. A research culture and institutional framework for innovation that presents a strong ideological model for others to emulate. A S&T superpower would underpin its international excellence with institutions that would directly or indirectly shape the global debate and exert dominating influence over science, technology and innovation systems in most countries.

The three dimensions outlined above could be seen as characterizing the United States as a S&T superpower (in addition to its current status as a military and economic superpower). The research capabilities of US top universities are respected everywhere, and a significant portion (34%) of Nobel Prize winners are from the US. Likewise, US universities attract talented researchers from all over the world, and innovative clusters such as Silicon Valley are central nodes of international networks, and have contributed significantly to technologies that have fundamentally changed economic structures globally. Transnational corporations from the US remain dominant in the development and diffusion of new advanced technologies. Finally, the cultural and institutional norms of US research practice, funding and evaluation are immensely influential globally, and are copied in many countries. The impact of US principles and institutions for intellectual property protection on international and national regulation (e.g. TRIPS) is also extensive.

The Soviet Union, despite its achievements in space and military technologies, never attained a similar S&T superpower status. After the development of strong technological capabilities in industries such as steel, automobiles, and electronics in the 1980s, Japan seemed the most likely candidate for a new technological superpower (Samuels, 199?), but the weakness of basic research capabilities and the difficulties experienced in promoting high technology entrepreneurship cast serious doubts on the prospects. Moreover, the financial crisis that struck Japan at the end of the decade also appears to have undermined efforts to create a dynamic S&T superpower system, even if observers recognize that Japan continues to generate Nobel Prize winners and frontier technological innovations (Fasol, 2005).

In contrast, I would argue that it is possible to see the United Kingdom as a declining, but still influential, S&T superpower, with universities and scientists that have dominated research frontiers for a long time, and still very attractive as a center for talented researchers from many countries. Transnational corporations originating in the UK are still close to innovation frontiers in some sectors, even if the range is not as broad as that of the US. Germany and France are other countries that have reached prominence in some dimensions, but which can hardly be characterized as S&T superpowers.

Key Trends of China's S&T Status

In this section, I wish to briefly review some of the key trends in science and technology in China, to form a background for an assessment of the status of the country as an emerging S&T superpower.

More R&D Input – More R&D Output

The most conspicuous trend noted in virtually every recent books or papers on China's science and technology system is the rapid growth of R&D investment since the 1990s. On the input side, there is the spectacular growth of R&D investment as a proportion of GDP, which has tripled from 0.6% in 1996 to 1.8% in 2010; considering the exponential growth rate of China's GDP during this period, the resources available for innovation in China are now substantial. Chinese firms accounted for 42.9% of the country's R&D

spending in 1997, and this figure rose to 60.3% in 2000 and reached 73.4% in 2010 – a ratio equivalent to those of advanced industrialized countries such as Japan and the US (Wu, 2012). Large and medium-sized Chinese enterprises – which account for 10 per cent of all firms, are major actors as they undertake 77% of total R&D investment by business and account for 68% of all invention patent applications. The relative share of domestically owned firms in business R&D investments in China is 74%, while the R&D investments of foreign-owned firms constitute 26% of the total (9% by firms from Hong Kong, Macau and Taiwan, 17% by other foreign- owned firms).

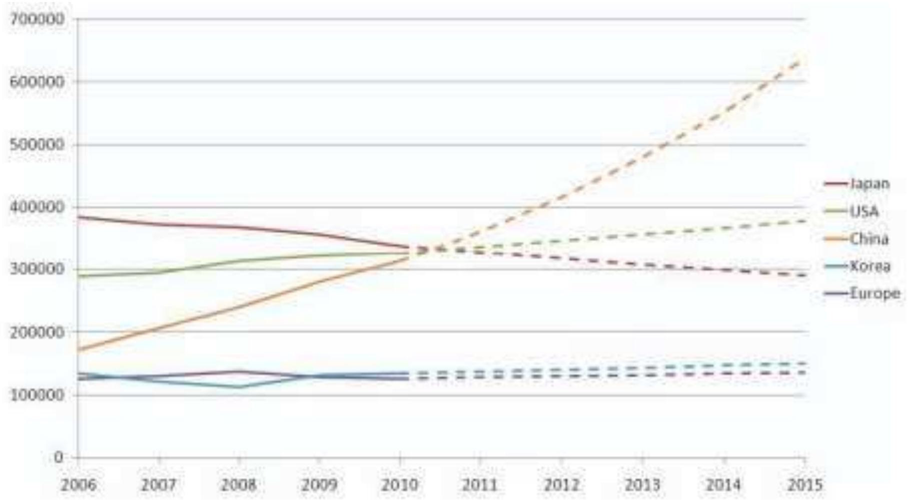
While these number indicate that business R&D has become an important driver of innovation in China, it is important to note that the large majority of these efforts and investments are concentrated on process and product development, and that the expenditure on basic science research only constituted 4.6% of total Chinese R&D expenditures in 2011 (Qiu, 2012), as illustrated dramatically in Figure 1 below. Nevertheless, public priorities in science and technology maintain a very important position in the China’s innovation system since they to a large extent influence the activities of research institutes and universities, but also because state-owned enterprises still dominate business R&D investments. It is also noteworthy that the universities have gained prominence in basic scientific research during a relatively short period of less than three decades.

Figure 1; GERD by Type of Activity

Source: China Science & Technology Statistics Data Book, 2011, Figure 1-2

In terms of output, the growth of Chinese patents appears to be the most immediate phenomenon associated with the expansion of R&D in China. Figure 2 illustrates this point in a spectacular manner, showing that Chinese patent applications are poised to become a quantitatively dominant factor in world patent activity, overtaking that of the USA and other industrialized countries.

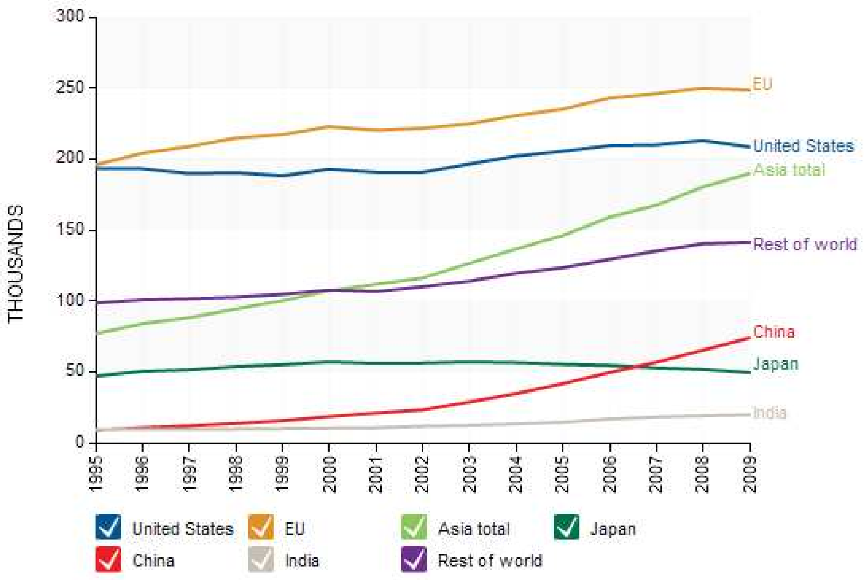
Figure 2: Projected Growth in Patent Applications



Source: Thomson Reuters (2011), p. 6

The growth of international scientific publications by Chinese authors shows an equally impressive quantitative growth. Recent statistics indicate that out of the world's 827,705 articles published in 2011, researchers in the combined 28 European Union countries produced 254,482 articles (31%), the United States 212,394 (26%), China 89,894 (11%) and Japan 47,106 (6%). Below, Figure 3 illustrates this phenomenon. The growth in scientific publications achieved by China and India contributes significantly to the general increase of the share of Asia in global scientific literature. In addition, the expansion of publication output from Korea and Taiwan is adding to Asia's share.

Figure 3: Science and engineering articles, by selected region/country: 1995–2009



Source: NSF S&E Indicators < http://www.nsf.gov/statistics/digest12/outputs.cfm#1>

At the same time, it should be noted that the growth of articles published has not yet been accompanied with a greater number of citations for Chinese articles or a significant growth in the relative impact factor for Chinese publications (Wagner, 2011). This is an indication of quality in terms of whether the published research has obtained a status as leading in the research field, rather than a question of the overall level of quality of published Chinese research as such. The peer review system of SCI journal ensures that a certain level of academic excellence is maintained in publications by researchers from China, as with authors from other countries and, no doubt, there are many significant contributions to the academic community by Chinese authors.

Nevertheless, there have been few scientific contributions by scholars from China that have been recognized as ground breaking by the global academic community, and the issue of developing world-leading discoveries continues to hold back Chinese scientists from obtaining the most coveted award of scientific excellence – the Nobel Prize in science. There have been eight Nobel laureates in science with Chinese ethnicity living abroad, but so far the only Nobel prizes won by Chinese from the PRC have been in literature and peace. The core issue may not be the lack of talented researchers in China, but the reluctance of the Chinese leadership to accept the values of modern science. Thus Cao (2014 argues that "China values science, but does not necessarily accept the values of science, which could be detrimental for its ambitions, including being awarded the Nobel Prize in science and becoming a real scientific power."

During the 20th century, the United States became a dominant scientific power hatching Nobel Prize Laureates, gaining a larger share of Nobel Prizes in science as Germany lost its share after the Nazi regime imposed its restrictive policies in the 1930s (Schmidhuber, 2010). In other words, the emergence of the United States as a S&T superpower was precipitated by its promotion of values of science and an academic culture of excellence and freedom that fosters scientific discoveries of the ground breaking nature that are awarded Nobel prizes.

Technological Capabilities

An essential aspect of gaining a status as a S&T superpower is the extent to which those achievements of S&T output listed above actually gets translated into widespread technological capabilities at the frontier. That is, whether there exist extensive domestic innovative capabilities in Chinese firms – beyond the technological achievements in high priority defense, space, or supercomputers. There is no doubt that it has been possible for Chinese organizations to upgrade their technologies utilizing foreign technology, and the utilization of foreign knowledge and technology remains an essential component of the emerging international competitiveness of Chinese firms. There is a small group of a dozen Chinese firms that most of the observers mention all the time –Lenovo, Huawei, ZTE, Haier, Alibaba – which have shown new strength in innovative products. However there are few among these firms, if any, that can be said to operate at the forefront of global innovation.

Thus, much of the advanced technological advance of Chinese enterprises that have grown out of indigenous efforts appear to have taken place in low and medium technology industries, while the high technology sectors are dominated by the technologies of foreign firms. Indeed, most of China's high-tech exports, which have attracted attention by observers of international trade, is in fact based on overseas design and know-how or produced by foreign corporations operating in China. Domestic R&D efforts have been far more significant for less technology-intensive sectors, and an analysis of advances in total factor productivity shows that more indigenous Chinese firms are located at the frontier in low- and medium-technology sectors (Fu and Gong, 2011). Another formulation of this is that China's innovative edge lies much closer to D than to R on the R&D spectrum: China's companies remain better at developing and improving existing products than at inventing new ones. It is of course possible to argue that it is precisely in this mundane area of innovation that China's competitive advantages exists, and therefore, that promoting such innovation is a clever strategy for economic development (Breznitz and Murphree, 2010).

Perhaps a more important point is that the combination of foreign and domestic technology development have played a crucial role in laying the foundation for technological capabilities in selected sectors where the competitiveness of Chinese firms has led to an emerging global position. This has been the case of the emerging prominence of Chinese firms and technological capability in mobile telecommunications, where the China-sponsored technical standard of TD-SCDMA has provided a potential avenue to global dominance – although the jury is still out on whether this strategy will succeed. Another pertinent example is the recent growth of capabilities in production of photovoltaic solar panels, where Chinese producers captured a major share of global markets in a span of a few years on the basis of efficient deployment of foreign knowledge and technologies. Again, the outcome in terms of providing Chinese industries with unique technological capabilities and competitive knowledge-based competitive assets is still uncertain.

One way that China may reach the status of a S&T superpower might be to develop prominent positions in areas of science and technology that are crucial for future economic progress and competitiveness, but which may not be adequately addressed by existing S&T powers. The area that naturally lends itself to this kind of strategy is traditional Chinese medicine; where there are reasons to believe that Chinese researchers and enterprises might have particularly strong backgrounds. In fact, almost half of Chinese patents in pharmaceutical products have been associated with traditional Chinese medicine. But there are also a number of other areas where the Chinese S&T system has gained a prominent position in the world, such as nanotechnologies and fields of biotechnology that involve stem-cell research.

Moreover, the environmental challenges faced by China today – including the urgent need to develop and diffuse low-carbon technologies for mitigation of climate change – present both threats and opportunities for China’s innovation system. In this respect, the recent emphasis on development and deployment of renewable energy in China makes sense from both the perspective of avoiding severe future consequences of climate change and from the perspective of gaining strong technological and industrial competence in the future. Another trend that could play an important role is an emphasis on the development of fourth generation nuclear power plants.

In addition, there are reasons to believe that advanced information technology and the Internet hold the key to future economic growth and business competitiveness. China has gained a better position than many emerging economies in this area, and the innovative entrepreneurship that we witness in China today may give the country vital advantages in the future.

International Cooperation and S&T Networks

An important source of knowledge for the Chinese S&T system has been international links in science; the exchange of scholars and postgraduate students has served to boost the quality of publications by Chinese scientists. Co-authored papers by Chinese and international scientists have expanded at a rate that was slower than the growth in the quantity of the scientific publications from Chinese authors, but the increase in citations for co-authored papers shows that international collaboration contributes to the quality of the Chinese researchers involved (Zhou and Glänzel, 2010). There is also evidence indicating that international cooperation provides a "dividend" for Chinese researchers, both in terms of high quality publications and through the transfer of methodologies and a scientific culture that further enhances the potential impact of publications (Tyfield, Zhu and Cao, 2009). However, it is also important to note that many participants from the US and Europe in formal international scientific cooperation projects with China are in fact overseas Chinese academics. This does not reduce the value of such international cooperation – on the contrary, it probably improves its efficiency – but it could shape the integration of Chinese research in international networks in ways that might concentrate its participation in limited areas, perhaps marginalized without access to exciting new discoveries.

The overseas training of graduate students and visiting researchers from China have become a premier source of knowledge and technological upgrading during recent decades. On the one hand, the phenomenon of overseas Chinese returnees, who have gone abroad for training and who return to China as high-skilled researchers, managers or entrepreneurs, has been identified as the source of crucial new competence in the research system and knowledge inputs in the high technology sectors (Saxenian, 2006). A recent study of patenting in the Chinese photovoltaic industry shows that a group of Chinese intellectual returnees who became leaders in new firms in the photovoltaic sector were more likely to file patents – and thus promote indigenous Chinese innovation in the sector – than the people who did not have an overseas background (Luo, Lovely, and Popp, 2013). There have been examples of returnees who did not find opportunities to fully exploit the skills acquired overseas, for instance, in the Chinese venture capital industry, where foreign-trained talent showed a lower productivity than locally-trained talent, possibly because of a mismatch between the skills of the foreign-trained staff and the demands of the Chinese market (Sun, 2013).

The ambition to utilize international sources of S&T for the upgrading of research and technological capabilities has been essential component of China's strategy for development. In particular, this was the case during the 1950s when large-scale cooperation with the Soviet Union enhanced Chinese capabilities, but even more so since the 1980s when Deng Xiaoping launched the Open Door policy. This policy of international cooperation has been intensified in recent years, while at the same time the avenues for access to new knowledge have been diversified for China. International joint ventures were important sources of technology transfer and training for Chinese enterprises during the 1980s, and they became particularly crucial technology transfer mechanisms during the 1990s. A study based on a World Bank industrial survey shows that positive technological spillovers took place in sectors where domestic Chinese firms had higher absorptive capacity, and was mediated primarily by the mobility or networks of highly educated labour (Hale and Long, 2006). But during the 2000s, as China joined the WTO, foreign direct investment shifted into wholly-owned foreign enterprises, and international joint ventures declined from half to just over one-fifth of foreign direct investment in 2007 (Van Renen and Yueh, 2012). It is likely that the opportunities for spillover effects would be reduced for wholly owned foreign firms, but then the expansion of domestic sub-supplier networks may offer opportunities for technology transfer and upgrading in domestic Chinese industrial firms. In fact, the transfer of knowledge and technology that takes place in supply chain relationships is an often underestimated informal resource for technological upgrading and innovation in Chinese industries.

The expansion of formal frameworks for international S&T cooperation serves to complement these sources of new knowledge and technological innovation in China, and bilateral agreements between developed countries and China often recognize this function of S&T cooperation explicitly. For example, from a European perspective, research cooperation with China provides new and additional opportunities for building competitiveness and solving key social and economic problems, by mobilizing the increasingly advanced Chinese research entities and scientists to contribute to the joint creation of relevant knowledge and innovation. From a Chinese perspective, the complementary resources of Europe and China provide a vital means of leveraging indigenous innovative capabilities, a point emphasized in China's EU policy paper from 2003 (Information Office…, 2003). Although formal international S&T cooperation thus functions as an increasingly important means to access and exploit global knowledge resources and advanced science, it is likely that most of the technology transferred to China will depend on the many formal and informal avenues that exist for China now, that is, migration of high-skilled talent, licenses of intellectual property, foreign investment, and supply-chain industrial linkages. As S&T capabilities in China become more sophisticated, it is also likely that exchange of knowledge and technology will become two-way relationships rather than one-way transfer, to actually obtain a real status of "mutual benefit" – not a relationship benefitting only one part.

One aspect that has not really materialized on a major scale is the migration of non-Chinese S&T talent to China. Despite several programs initiated in recent years, the majority of foreign researchers still do not see opportunities for working in Chinese universities or research institutes as crucial to promoting their career – in the way they would probably regard a position in a leading university, research organization, or high technology firm in the US. With the ongoing process of improving research facilities and raising the level of research that takes place at universities and research units in China, this may change in the coming decades. The development of S&T superpower status, according to my definition outlined earlier in this paper, should emphasize a position as a key node in international networks of scientific and technological progress. This implies that the superpower is contributing actively to the development of global goods and to the solution of global problems, and thus will not be constrained by a narrow techno-nationalist perspective on innovation. In other words, the S&T superpower would naturally engage in what has been termed "cosmopolitan innovation" (Tyfield and Urry, 2009), and thus be engaging and cooperating extensively with global partners to promote innovative S&T projects. In other words, China would move towards obtaining a central position in international scientific and technological exchanges and networks – a position that perhaps require a much higher level of contributions of Chinese funding and other resources to global endeavors than is currently the case.

Conclusions

In this concluding section, I wish to address what I see as key implications of the foregoing analysis, and then speculate a bit about the future in terms of three scenarios. There are many questions that require systematic and extensive answers – which I find it very hard to give at the moment. But I shall provide tentative observations and interpretations which I hope will add some ground for further investigations in the future. First, is China likely to emerge as a S&T superpower in the immediate future? Secondly, how do we interpret the trends in emerging S&T strengths that we see? Thirdly, what is China's strategy for becoming a S&T superpower? And will it become just another superpower, or will we see a different kind of S&T superpower emerging in China?

Is China an Emerging S&T Superpower?

By the three criteria that I formulated to evaluate whether a country is reaching the status of a S&T superpower, China does not yet possess the excellence that positions its scientific research institutions as world-leading, even if I am persuaded that research in key organizations may be able to support world leading, original research achievements. Quantitatively, the overall support for fundamental scientific breakthroughs is still not enough to ensure more than selective, but limited world-class achievements; qualitatively, the research culture and institutional framework do not, in my view, support the academic creativity, maverick ideas, and originality which usually characterize groundbreaking discoveries that would harvest Nobel Prizes in natural science and medicine.

China has attracted talented scientific researchers and innovative entrepreneurs from overseas in recent years. However, the vast majority of these people have been of Chinese ethnicity, and although there is now an encouraging number of non-Chinese scientists who come to China for research opportunities, the country and its scientific institutions have not yet reached the status where they provide major attraction globally. But in a decade or two, I would surmise that several Chinese organizations would be highly attractive, and that it would become a major benefit to the CV and job opportunities of a talented foreign scientist to have joined them. Similarly, if China continues its open door policies, I would expect more innovative entrepreneurs to start up in China during the next decades, benefitting from the supportive business environment and market.

The institutions of science and innovation in China have been transitioning to a Western model recently, and it is doubtful whether the aspects which appear to be legacies of traditional Chinese culture and former management patterns of S&T in China – such as plagiarism or minute planning – holds much sway in international contexts. Nevertheless, the Chinese state's ability to concentrate scientific and technology resources on priority projects, such as nuclear bombs and space technology, commands a lot of respect in developing countries.

How to Interpret Trends in China's S&T?

Most of the observers discussing China's emergence as a technological superpower have utilized our standard thinking of linear or exponential projections. This reflects our instinct of seeing progress largely in terms of path dependence: scientific discovery and technological innovation follows definite paths, and it is difficult or impossible to shift to a radically new path or paradigm. China is seen as "catching up" or even "overtaking" other superpower(s) in what they are doing. Chinese developments in nuclear weapons, missiles, space, and other military technologies fit into this picture, as do the efforts to build supercomputers, airplanes, integrated circuits, etc. This is also the interpretation that assures Steinfeld (2010), as he observes the Chinese efforts at "institutional outsourcing" to emulate Western capitalist systems and high tech developments.

But what if China was to engage in disruptive innovation? What if there were nascent trends in scientific research or innovation in China that would break with the existing path – somewhat in the way that computing and communication power, together with the incredibly powerful TCP protocol, the Hypertext Transfer Protocol (HTTP), and the HTML language for the Internet has overturned our economies and business structures? What if a new drive to develop low-carbon technologies actually were able to take off in China, opening up a whole new era of resource and energy exploitation, shifting China's development away from its current track of environmental degradation and dangerous growth in carbon emissions?

What is China's Strategy?

Questions such as these prompt me to speculate about what China's strategy to become a S&T superpower is, or what it should be. It seems to me that the Chinese leadership is still seeking to emulate the US as a superpower, both in the military/political sense and in its priorities of S&T development. An ambition to send a Chinese astronaut to the moon strikes me as really pathetic – and wasteful. The professed aim of Chinese military strategy is to maintain "harmonious relations" with other powers and neighboring countries; the development of military science and technology should uphold this priority in the strictest sense, and not aim to bully less powerful countries or regions close by or far away.

I believe that China should use its emerging status as a S&T superpower to become a genuine world leader in scientific research and technological innovation that will push the global community in the direction of a new and sustainable economy and perhaps even help the human species survive into the next century. Recall that Dukes (2000) argued that a superpower must be able to conduct a global strategy "including the possibility of destroying the world." While I am sure that he was referring to nuclear apocalypse, it seems to me that both the existing and emerging "superpowers" are too eager to destroy the world with their carbon emissions; would it not be great if at least one emerging superpower had a different agenda?

In other words, I wish that China would utilize its strategy for developing indigenous technology to lead the world down genuinely new S&T paths, and not merely to protect the isolationism of vested interests and "kick away the ladder" for those that want to share in innovative progress. I wish that China would expand its current efforts to engage in international S&T cooperation at all levels and seek to undertake real cosmopolitan innovation, addressing key global problems and leading the international S&T community into vital new areas of research and innovation. I am certain that if the vast S&T talent and resources of China are led into such constructive – and not destructive – avenues of development, both the Chinese people and the rest of the world will benefit immensely.

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