Technological Advances in Key Industries in China

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Technological advances in terms of development, production, and exports are moving steadily forward in China. Broad inputs include annual growth in research and development (R&D) expenditures of 20 percent since 2000, more than 600,000 college graduates per year in engineering and computer sciences, and 20 percent or more annual growth in patent applications and science and engineering articles. Chinese exports in their definition of "Hi-tech products" doubled from $166 billion in 2004 to $348 billion in 2007, with a surplus of $61 billion in the latter year.

What this all means for new technology application by sector, however, is less clear, and in-depth, up-to-date assessments by industry sector are sparse and inadequate. Within these constraints, the presentation here is in three parts: a current best reading of technological advances for six key sectors; a commentary on the role of foreign firms as related to the new Chinese policy of "indigenous innovation"; and recommendations for more in-depth and up-to-date assessments of Chinese performance by sector.

Technological Advances for Six Key Sectors

The following are current readings of technological advances in China for six key sectors. They vary in content and are in general inadequate, but at least they provide the broad thrust of developments under way.

Aerospace. China is devoting large resources to develop advanced technology aerospace programs, with extensive overlap between commercial and military objectives. It plans to launch more than 30 commercial satellites to form the Beidou global earth observation system, called "Compass" in English, with initial coverage of China and parts of Asia by 2008. This system will become a competitor to the U.S. GPS system, and its early launch will give it a timing edge over the European Galileo system. The Chinese commercial satellite program is moving forward in parallel with its military program, including the January 2007 testing of a direct assault anti-satellite (ASAT) weapon, which was widely criticized as a military space program. China also put its first astronaut in space in 2003, launched its first lunar satellite in 2007, and plans a manned landing on the moon at some future point. Other areas of technological development related to space include military missiles and

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weapons and, on the civilian side, projects sponsored by the Chinese National Astronomical Observatories (NAO), including the "Giant Eye" telescope which could have the highest spectrum-acquiring rate in the world, the SST spatial telescope for international solar space research, and an infrared vacuum solar tower for solar physics. Also within this sector, China is making progress in developing small and medium size commercial jet aircraft, with the longer term goal of large body aircraft in competition with Boeing and Airbus.

Nanotechnology. In 2005, a U.S. task force report, "The Knowledge Economy: Is the United States Losing Its Competitive Edge?," concluded that China "has been investing heavily in nanotechnology and already leads the U.S. in some areas."[2] Subsequent reporting has confirmed this assessment.[3] The Chinese Academy of Sciences knowledge innovation program, launched in 2001, gave high priority to nanotechnology. The program currently includes at least 20 academic institutions, 1,000 to 1,200 scientists as principal investigators, and another 2,000 graduate students as assistants in nanotechnology research. The Shanghai Nanotechnology Promotion Center spent $126 million from 2001 to 2006 to train 1,500 scientists and engineers on the use of specialized equipment and machinery. Government financial and tax incentives promote technology transfer from labs to firms, with a heavy focus on small, start-up companies. In Shanghai alone, there are an estimated 100 to 200 small- and medium-sized companies doing nano-related work. Chinese nano-related publications in scientific journals are second only to the United States, and growing rapidly. China also plays a lead role in commercial application, with more than 30 product lines using nanomaterials, including for textiles, plastics, porcelains, lubricants, and rubbers. China is already a world leader in nanomaterials application, such as coatings and composites.

Biotech. The same 2005 U.S. task force report concluded that China "is making rapid progress in biotechnology." The two subsectors involved are agro-biotech, principally genetically modified (GM) crops, and medical science. China spent about $400 million in agro-biotech activities in 2007, and this could double by 2010. The government employs 2,000 scientists in 200 research labs. GM crops have been approved for tomatoes, sweet pepper, and papaya, and are being field tested for rice, corn, wheat, cabbage, cauliflower, soybeans, cotton, melon, and tobacco. GM crops have thus far been directed to the domestic market, but the demand for food is expected to soar throughout Asia, and Minister of Science and Technology Xu Guanhua predicted that agro-biotech "could become the fastest growing industry in China in the next 15 years."[4] In 2006, China had 3.5 million hectares of GM crops in cultivation and is thus in sixth place behind the United States (54.6 million), Argentina (18.0 million), Brazil (11.5 million), Canada (6.1 million), and India (3.8 million).[5] Medical science is a priority area for Chinese government laboratories. Chinese Academy of Sciences funding was $1.1 billion in 2005, triple that of 1997, and is scheduled to grow another 70 percent by 2010. Within the Academy program, research on infectious diseases receives high priority in view of political anxiety about the spreading within China of lethal diseases such as acute respiratory syndrome (SARS), bird flu, and HIV. French scientists are assisting to build a laboratory in Wuhan for diseases such as SARS and Ebola that could become the most sophisticated in Asia. A major obstacle to innovation by Chinese firms in the medical science sector is weakness in regulatory procedures for quality standards, with resulting faulty-product scandals, and delays in product approval, all of which is under review by the government.

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[2] See www.futureofinnovation.org, February 16, 2005. The Task Force consisted of 21 academic and private sector organizations and companies, including the American Electronics Association, the American Physical Society, the Materials Research Society, Intel, Lucent, and Microsoft.

[3] All of the material in the remainder of this paragraph is from Richard P. Appelbaum and Rachel A. Parker, "China's Bid to Become a Global Nanotech Leader: Advancing Technology Through State-Led Programs and International Collaboration," *Science and Public Policy*, 2008. This is a rare example of a thorough sectoral assessment of technological advance in China.

[4] See Salamander Davoudi, "China to Quadruple Agri-Biotech Spending," www.ft.com, March 15, 2007. The preceding figures in this paragraph are from this article.

[5] See Kathryn McConnell, "Asia Seen As Next Focus of Agricultural Biotech Production," www.gov.ei/economic_issues/biotechnology, February 16, 2007.

Information technology and telecommunications (ITT). Innovation and applied new technologies in this sector have been top priority for the technology-driven economic transformation of China toward becoming an advanced technology superstate. The specific scope and degree to which ITT innovation is taking place is wide ranging and complex—and poorly reported. The relative roles of indigenous and foreign company innovation are especially unclear. Principal specific areas for investigation include semiconductor design, high performance computers, telecommunications equipment, and software application. Some specific observations: 450 semiconductor design companies have elevated China to second place in this area, still far behind the United States, but closing the gap; the Godson II central processing unit (CPU) computer chip to support the 64 bit Linux operating system was the first high performance CPU chip for which China has proprietary property rights; and the Dawning 4,000A Shanghai Supercomputer can operate at 10 trillion calculations per second, a speed that puts it third behind U.S. and Japanese supercomputers. Chinese military modernization involves a wide range of ITT innovation, including for ballistic missiles, secure communications networks, and cyber warfare programs, increasingly performed by Chinese companies also engaged in commercial markets. Almost all of this range of military-related innovation is, of course, highly secret.

Automotive. Chinese vehicle and automotive parts producers are becoming more engaged in innovation, but R&D expenditures remain well below those of the multinational foreign companies, and it is unclear how much indigenous innovation will emerge. A wide range of auto parts are constantly upgraded through more advanced design and new technology application. Hybrid and other new engines are under development within Chinese companies, but with little to show for it through 2007. China has always limited foreign investment in vehicle production to 49 percent of joint ventures. The intention is that Chinese partners will ultimately become independent producers, with a strong capability for innovation, but this remains a future hope.

Pharmaceuticals. Chinese development and innovation in the pharmaceutical sector has been expanding rapidly, principally through collaboration between Chinese and foreign firms. An example is the Swiss firm Novartis, which is building a research facility in Shanghai that will have 500 scientists as an integrated facility to perform early drug discovery and clinical tests. Innovation start-up companies abound, and some are engaged in the subcontracting of testing for U.S. companies. Chunlin Chen, CEO of the contract research company Medicilon, states that "a research dollar spent in Shanghai can stretch several times further than it would in the U.S."[6] A June 2008 study based on extensive interviews with 16 Chinese and Indian pharmaceutical companies concluded: "Big pharmaceutical companies . . . are now counting on these countries for research and development. . . . Both nations have become major partners in preclinical and clinical testing. . . . India is playing a more strategic role in early discovery. . . . It is too early to tell whether China and India will become important sources for new drugs. . . . The early progress, however, is promising."[7]

The Role of Foreign Firms and the New Policy of Indigenous Innovation

Foreign-invested firms have played a decisive role in the development of advanced technology industries in China, particularly for export-oriented manufactures, and for the information technology and electronics sectors most importantly of all. The Chinese government gave strong incentives to such foreign investment, including the unusual step of lower taxes for foreign compared with domestic investors. In some key respects, however, the participation of foreign firms is frustratingly unclear. There is little available information on the breakdown in R&D expenditures between foreign and domestic firms, or on the share of foreign investment in university-based basic research

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[6] See Jean-Francois Tremblay, "China Strides Toward Global Pharma Role," *Chemical & Engineering News* (American Chemical Society, March 12, 2007).

[7] Vivek Wadhwa, *et.al.*, *The Globalization of Innovation: Pharmaceuticals* (Kauffman: The Foundation of Entrepreneurship, June 2008, p. 20). The Duke/Harvard University team headed by Wadhwa also conducted interviews in the two countries for the semiconductor, automotive, aerospace, call-phone, and computer-networking sectors, and reports on these sectors are forthcoming.

programs. There are also divergent assessments as to the shares of domestic and imported components utilized by foreign firms for exports.[8]

There is no question, however, that foreign firms are responsible for the large majority of Chinese exports. The share of total merchandise exports by foreign firms and joint ventures rose from 48 percent in 2000 to 57 percent in 2007. More startling was the September 2007 Organization for Economic Cooperation and Development (OECD) report indicating that the share of Chinese high-technology exports by foreign firms and joint ventures increased from about 65 percent in 1996 to almost 90 percent in 2005.[9]

In recent years, under the Hu government, in contrast to its predecessors, this policy of favoring foreign firms has been reversed and replaced by a policy of "indigenous" or "independent" innovation, meaning special incentives and preferential treatment for Chinese over foreign firms. The formulation of this strategy by a large group of scientists, engineers, economists, and corporate executives during 2004-2006 was controversial, and described as follows: "Some Chinese economists argued strongly that at China's current level of economic development . . . the most cost-effective way to upgrade China's technological capabilities would be to continue to encourage technology transfers from multinational corporations. . . . Most members of the technical community rejected that thinking and argued that foreign corporations could no longer be counted on to transfer technologies. . . . They claim that China's technical gains from multinational corporations were disappointing. . . . In addition, China had become increasingly dissatisfied with the relative gains it was accruing. . . . The royalties Chinese firms had to pay for foreign technology . . . often seemed excessive. . . . The advocates of a strategic S&T policy to strengthen indigenous R&D clearly have won out."[10]

The new strategy of economic nationalism with respect to technological innovation was confirmed in December 2006, during the first meeting in Beijing of the U.S.-China Strategic Economic Dialogue, headed on the U.S. side by Secretary of the Treasury Henry Paulson, when Chinese Vice Premier Wu Yi stated, "China will take enhancement of innovation capability as the strategic starting point for scientific and technological development . . . [and] endeavor to achieve breakthroughs in strengthening the ability of independent innovation."[11] The implementation program of the new strategy is comprehensive, with ambitious goals set for increased R&D in the targeted sectors of energy, manufacturing, aerospace, and biotechnology. There are 17 designated engineering and scientific megaprojects, including advanced numeric-controlled machinery, extra large scale integrated circuits, manned aerospace and moon exploration, new-generation broadband wireless telecommunications, and nanotechnology. Implementation of the program, however, remains ill-defined and is moving slowly, reflecting continued controversy. Several initial steps are nevertheless of growing concern to foreign investors, such as the 2006 Revitalization of the Industrial Machinery and Manufacturing Industries program and the November 2007 revised guidelines for foreign direct investment in "strategic and sensitive industries relating to national economic security."

While the outcome of the new indigenous innovation strategy remains largely to be seen, there is no question that it is an important change of direction, which casts a cloud over the future course of Chinese advanced technology industry development, and over high-technology exports, in particular, in view of the predominant foreign firm role up to this point. Just three broad observations are offered here on factors that will influence the course ahead:

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[8] See Preeg, *op.cit.*, "The Fading Export Platform Issue," pp. 71-73. The conclusion is that the share of Chinese valued added in high technology exports is now 60 percent or higher, and continues to rise along with the soaring Chinese trade surplus in these sectors. Other observers believe the share is much lower.
[9] OECD Reviews of Innovation Policy: China, Synthesis Report, September 2007, p. 14, Chart 1.15.
[10] The background and contents of the plan are described in Cong Cao, Richard P. Suttmeier, and Denis Fred Simon, "China's 15 Year Science and Technology Plan," *Physics Today*, December 2006, pp. 38-43. The quote is from page 41.
[11] Vice Premier Wu: China's Development Road, December 14, 2006, gov.cn.

A relative decline in competitiveness for foreign-invested firm R&D. This is the direct effect of the new strategy which is designed to give an immediate competitive advantage to Chinese over foreign firms for technological innovation and, over the longer term, to elevate them to the dominant position within broadly defined strategic sectors. This does not mean that foreign firms will reduce or shut down R&D activities in China, but the growth in R&D might be directed to more attractive investment climates elsewhere. India, for example, has recently been attracting large new foreign R&D commitments, including by Cisco and Nokia to locate their principal overseas R&D operations in India.

A relatively slower pace of indigenous innovation. This reflects the view of the Chinese economists cited above who believe that the most cost-effective way to upgrade China's technology capability continues to be to encourage technology transfers from foreign firms. Chinese firms are more and more deeply engaged in R&D, but in current circumstances innovation may be slower to materialize in some sectors if limited to Chinese firms. The OECD report concluded that "China will need to improve the framework conditions for innovation, including good corporate governance and a modern and pro-competitive regulatory regime, in order to strengthen the basis for long-term growth."[12] Thus, if the indigenous innovation strategy is pushed too fast and too far, the innovation momentum in China could suffer.

The exchange rate factor. The misaligned, overvalued Chinese currency is of increasing concern for Chinese trading partners as the Chinese export surplus in manufactures continues to soar. The trade surplus in the sector rose from $45 billion in 2000 to $465 billion in 2007, and was up by a stunning 32 percent in January-May 2008 compared with 2007. The trade-weighted exchange rate for the yuan since 2005, however, has been slightly down. A historical comparison with the 1980s, when the U.S. trade deficit with Europe and Japan was of much smaller proportions, was the resulting Plaza Accord, after which non-U.S. currencies rose 50 to 70 percent. A large revaluation of the yuan will thus be required to begin to reduce the Chinese trade surplus and related central bank purchases of foreign exchange. It is not possible to predict when or by how much the revaluation will be, but the direction of change and its impact are clear: a relative decline in Chinese cost competitiveness for R&D and other innovation-related operations, and thus a slowing of the overall innovation process.

The Need for Improved Assessments of Chinese Performance by Sector

One important conclusion from all of the above is the need for more systematic, in-depth, and up-to-date assessments by sector of technological advances in China. A couple of examples were provided of recent in-depth sectoral studies of the nanotechnology and pharmaceutical sectors, but overall the sectoral coverage is uneven, and the approaches differ greatly, making comparative assessment among sectors especially difficult.

A common and coordinated approach to assessment by sector would therefore be useful for several reasons. It would provide a more accurate and up-to-date understanding of the impact of Chinese technological advances on U.S. export competitiveness and continued leadership in technological innovation. It would help generate public understanding of what is at stake as a prerequisite for an effective U.S. policy response. And it should be of mutual interest to both China and the United States, in order to pursue, on a more cooperative basis, the mutual benefits from a faster pace of new technology development and application.

More systematic sectoral assessments can best be addressed by the people who know the sector through private sector engagement or close monitoring from positions at a university, with a consulting firm, or within the government. A team of such people could produce a reasonably comprehensive assessment of recent developments in China with respect to innovation, advanced

[12] OECD, *op.cit.*, p. 60.

technology production, and exports, including the respective roles of indigenous and foreign firms. A first step would be to develop a common sectoral model of questions to be addressed and basic information to be collected. A common study format for all selected sectors would be especially helpful for assimilating individual sectoral assessments into a broader analysis of technology-driven industrial modernization and innovation in China. It would also be more user-friendly for readers trying to understand what is happening.

There are various places where such sectoral assessments could be developed and managed. The overall initiative could be coordinated, for example, by the National Academy of Sciences or the Sloan Foundation Industry Studies Program. The lead management role for specific sectors could be given to universities with programs already engaged in studying particular sectors, such as by the Duke/Harvard team, consulting firms with experience in such sectoral analysis, or industry associations. Individual participants could include senior corporate managers closest to R&D and new product development in China, academic and consulting experts, and government experts from the economic departments.

A broader question is whether such a sectoral assessment initiative should be limited to China, and the emphatic recommendation here is that it should address both China and India. These are the two emerging advanced technology superstates, engaged in deepening competition with a strong technological underpinning at all levels, and together with the United States forming a new Asia-Pacific triangle of far-reaching consequences for the global economy and the world political order.

Finally, there should also be a broader international interest in such sectoral analysis, and a multilateral approach could be developed, most readily within the OECD Science and Technology Directorate. Directorate experts would manage the analysis, with the participation of public and private sector expertise from member countries and nonmembers China and India. China has been a nonmember participant in Directorate activities, including at the annual ministerial level meeting, for several years, and India has recently expressed interest in selective participation in OECD activities. Such OECD institutions, however, would probably take considerable time to organize, and would benefit from the experience and results of a faster-off-the-mark U.S. initiative. The suggestion here, therefore, is to begin sectoral assessments within a U.S. structure, while, in parallel, initiating discussion of OECD studies with broader international participation.

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The bottom-line assessment is that technological advances in China are strongly under way throughout key industry sectors. The specifics by sector, particularly with regard to technological innovation and application, are sketchy, but the leading-edge indicator, exports, leaves no doubt: In 2007, 58 percent of total merchandise exports were in the broad category of "machinery and electronics," while the share for apparel was down from 14 percent in 2000 to 9 percent. This presents a major challenge for strengthening U.S. export competitiveness and maintaining leadership in technological innovation. There are important uncertainties as to the course ahead. Some uncertainties about the Chinese course related to implementation of the new indigenous innovation strategy were discussed above. Uncertainties about the U.S. policy course ahead will be equally decisive, and the policy response[13] should get front and center attention from the presidential candidates now and from the new administration next year.

[13] The U.S. policy response needs to be comprehensive and forceful, as presented in Preeg, *op.cit.*, Chapters 7-11.