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The Civilian High-technology Economy: Where is it heading?

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I would like to thank the Co-chairs and the other distinguished members of the Commission for the opportunity to speak to you today. It is an honor to be invited.

My focus today is on commercial, civilian high technology sectors. Developing the civilian technology sector and indigenous technological capabilities is an important strategic, political, and economic priority supported by the country's highest leadership. The January 2006 Mid to Long Term Science and Technology Plan, for example, calls for the "strengthening of independent innovative capabilities," [zizhu chuangxin] and the "building of an innovative country." In most public pronouncements, these capabilities are clearly linked with economic goals as well as national power and prestige. Speaking about the Mid to Long-Term Plan, Premier Wen Jiabao, for example, argued that without "independent innovation", China would be unable to claim an equal place in the world.

The assumption here is that new capabilities in commercial high-technology sectors eventually improve the military capabilities of the People's Liberation Army (PLA) in at least two ways. First, the civilian economy produces increasingly sophisticated products that are dual-use and are readily available to the military. New capabilities in the telecommunications sector have clearly assisted in the development of new C4ISR[1] capabilities. Second, technologies and skills developed in the civilian sector gradually migrate over to defense production, significantly improving both the process and product of the defense industries.

Chinese policy makers are working to ensure that the civilian economy makes a more direct contribution to defense modernization. Policies like the 863 and 973 plans straddle civilian and defense S&T agencies and foster the development of critical dual-use technologies such as information technology, aerospace, and lasers. At the same time, Chinese policy makers have begun the process of dismantling many of the barriers between civilian and defense R&D as well as creating new institutions to promote cooperation between the defense S&T establishment and its civil counterparts. Here the goal is to harness the private sector for military use [, yujun yunmin].

This is a dynamic and uncertain process. China's new economy is still taking shape. The civilian science and technology (S&T) system has expanded rapidly and continues to attract significant resources. Signs of progress are increasingly prominent: in 2005 China passed the United States to become the world's leading exporter of mobile phones, laptop computers and digital cameras and, according to the World Intellectual Property Organization, climbed to 10th in world rankings for patent applications

Still there remain distinct institutional, political, and economic weaknesses that may severely limit efforts to foster greater innovation. The current civilian S&T system is increasingly one of pockets of excellence at the regional and firm level, rather than one that is fostering a widespread, systemic process of innovation.

The demands of innovation may also conflict with the desire to have the civilian economy better serve defense modernization. Innovation is best fostered through the removal of the state from the economy and decentralization. Specific policies designed to promote the development of dual-use technologies in the civilian economy may in the long-term distort the market and make systemic innovation less likely.

In my comments today, I will briefly describe the main policy tools that the Chinese have deployed in efforts to create a more innovative civilian sector. I explain the factors behind the increasingly vitality of the civilian S&T sector in the 1990s, and point to some of the strengths of the larger innovation system as we look to the future. In the next section, I look at some of the institutional weakness in the civilian S&T system and describe three critical choices faced by the current leadership over the next three to five years. The brief conclusion raises two analytical issues.

Creation of a more innovative economy

Over the last twenty-five years, the S&T reform process has consisted of technology import and the development of domestic technology capabilities. These two strategies are of course interrelated and the focus between the two has shifted back and forth as policy makers identified problems in development policies.

In the realm of domestic technology development, Beijing has 1) devoted greater resources to S&T; 2) shifted R&D out of state research institutes to industrial enterprises; and 3) welcomed and encouraged the participation of domestic non-state enterprises.

Total R&D expenditures have gone from about .6% of GDP in 1995 to 1.5% in 2005 and the goal for 2020 is 2.5%; total R&D equals about $108 billion in 2004 and is expected to top $139 billion in 2006. [2] The 863 Plan, the Key Basic Science R&D Program (973 Plan), and Key Technologies R&D Program support research in dual-use areas such as information technology, biotech, space, energy resources, automation, and lasers; funding for the three programs totaled approximately $1.4 billion in 2004. [3]

One of the main objectives of S&T reform strategy has been to increase the importance of industrial enterprises. Much of the R&D occurring in the Chinese system during the 1970s and 1980s was bottled up in state research labs with little hope of ever being commercialized. In an effort to break the barrier between research and production, enterprises are playing a greater role in innovation. The enterprise sector in China has increased its total share from below 50% to 60% of total R&D expenditures in 2004.

As a complement to the SOEs, technology planners have fostered and supported new non-governmental enterprises (minying keji qiye) "spun-off" from state research institutes, universities, and state-owned enterprises. [4] The Chinese Academy of Sciences (CAS) was the home of many of the most famous and successful enterprises during the 1980s, but the pattern of firm creation and growth was similar no matter what the home institution.[5] New enterprises were "spun off" CAS by entrepreneurial individuals, often with start-up capital provided by CAS. CAS typically made these enterprises loans that would be paid off once the company became commercially successful. In most instances these enterprises commercialized technologies originally developed in CAS institutes, set up offices in CAS buildings, and were staffed with CAS research personnel.

In addition to regulations directly tied to nongovernmental enterprises, officials also created new policies designed to provide more extensive financial support for R&D and the commercialization of scientific products. The most important of these was the Torch Plan, initiated in May 1988, and the most important component of the Torch Plan was the development of science parks and high-technology development zones.

The experience of Silicon Valley, Route 128, and other science parks had a strong impact on China. In all of the zones, the underlying logic was the same: concentrating universities, research institutes, and production units in the same area and providing the necessary infrastructure and preferential tax and finance policies would attract technology enterprises and S&T personnel, eventually creating new clusters of regional innovation. The geographical concentration of high-tech firms and institutes of higher education was expected to generate positive externalities through information exchanges and knowledge spill-over. [6]

Technology Import

In the realm of technology import, there has been a gradual shift away from importing machinery and equipment toward the encouragement of foreign investment and the role of MNCs. At the onset of the reform era, control over technology import was decentralized to localities and parceled out to central government ministries. These agencies often rushed to import "high tech" machinery they did not need or did not know how to use, and, as a result, the central government re-imposed itself in the mid 1980s, playing a larger role in brokering technology import projects. At the same time, foreign investment was beginning to be encouraged, but it was limited to various enclaves defined by the Chinese government. Foreign investors were generally denied access to the domestic market, were required to export, and had to balance their own foreign exchange needs. When access to the domestic market was granted, it generally followed an individual case-by-case determination by the relevant Chinese authorities that the technology involved was critical to economic development.

The investment regime was dramatically liberalized in 1992-1993—foreign invested enterprises (FIE) were given much greater access to the domestic market. Foreign investment soon flooded into the market, much of it in medium to high technology sectors. FIE exports, which had originally been predominantly clothing and toys, began to include a substantial share of electronics assembly and other production associated with high technology sectors. The reliance on FDI inflows—which since 1993 has surpassed 5 percent of GDP—has meant that MNCs were playing a dominant role in overall technology import.[7]

The focus of contemporary policy is less on maximizing the flow of technological capabilities into China than it is on maximizing the ability of Chinese domestic firms to master the new technologies flooding into China. Here firms like Huawei and TCL are good examples of the trend, at times competing against and at other times cooperating with foreign firms. Both receive government assistance—often through direct bank loans and state procurement—and seek to compete less on recreating core technologies and more on assembly, design, and systems engineering.

What explains the first wave of success?

During the 1980s and 1990s, progress in the reforms, especially in the development of the nongovernmental sector, was the result of several factors. First, with their hybrid structure and undefined property rights, nongovernmental enterprises had access to technology and capital from both the state and the market. Undefined property rights facilitated movement of R&D into the market that had been accumulating in the state system for the first thirty years of the PRC. Perhaps more importantly, these firms also had access to appropriate partners. More likely than not, these were state agencies that were the companies first customers, helped new firms make sense of the complicated thicket of rules and regulations, and may have even helped land other contracts. These agencies also defended smaller firms from overzealous local officials who may have been inclined to levy "fees" or illegal taxes on small enterprises.

Second, *minying* enterprises were the first to develop new products. Moreover, nongovernmental enterprises entered market areas—software, bioengineering, and new materials—that were completely new and so lacked bureaucratic organs with sectoral authority. Once nongovernmental enterprises tried to enter market niches where ministries already had a strong presence, like photo-mechanical electronic integration, they faced strong competition from enterprises under the control of the Ministry of Mechanical Industry and the Ministry of Electronic Industry.[8]

Third, nongovernmental enterprises took advantage of direct foreign investment and trade relations with multinational corporations. All the large enterprises had representative agreements with enterprises like IBM, Compaq, Apple, and Hewlett-Packard. Distribution agreements with MNCs provided much needed investment capital as well as access to an already established global network of foreign partners and proven organizational structures and management skills.

What does China have going for it in the next wave?

First and foremost, China's market in IT sectors is big and growing rapidly. Chinese Internet users numbered over 100 million in 2005, and fixed and mobile lines exploded over last five years. Mobile users now exceed fixed line users. On the production size, growth is equally impressive. China is now a major producer of handsets, laptops, and printers. Perhaps most importantly, China has a growing consumer class that is increasingly technologically sophisticated and demanding. According to the marketing firm Grey Global Group, it is now fashionable to upgrade cell phones every three months in China. Philips Semiconductors Executive Vice-President Leon Husson predicts "we will see China in a few years going from being a follower to a leader in defining consumer-electronics trends."

Second, the Chinese economy is incredibly open to trade and FDI. Here a comparison with India is useful—last year FDI flows into China were $60 billion compared to $5.3 billion for India. At issue is not only the availability of capital for domestic enterprises, but also the widespread transfer of technology and management skills that have occurred in joint ventures with foreign companies.

The presence of foreign companies has also significantly raised the competitive pressure on domestic companies. The most successful parts of China's technological development are likely to be the areas where innovative domestic firms are closely related to foreign invested firms, engaging in complex relations of supply, cooperation and competition. For example, in electronics, Chinese domestic firms have quickly found niches in which they could cooperate with MNCs. Although their initial entry has typically been in relatively low-tech, labor-intensive assembly phases, these firms have been in a position to move gradually but steadily into slightly higher technology stages of the complex electronics production chains.

Third, China can exploit the skills of an increasing number of returnees. The advantages are not only in the numbers—estimated returnees for 2004 total about 25,000—but also in the skills the returnees are bringing with them. During the late 1990s and the first wave of returns, the average technology returnee may have had an MBA but little actual industry experience. Now people are returning home after spending five to six years at US companies in Silicon Valley or Route 128 outside of Boston.

Finally, Beijing has a strategic view of technology. China's leaders can mobilize resources from top-down and animate policies with a sense of national purpose. Back from their most recent trip to Beijing, American CEOs often quickly praise China's leaders for "getting technology", giving the sense that China is moving rapidly in the right direction.

Continuing Challenges

What all of this adds up to is an open question. For every measure of Chinese progress, these are serious questions about what they mean for the creation of an innovative economy. High-tech exports are up, but sales from foreign-invested firms make up a majority share of those exports, and are growing in some critical sectors. It is widely reported that China trains 600,000 engineers a year, but McKinsey reports that most do not have the language and practical skills needed to work in a multinational. The number of patents and scientific papers are both up, but patents and papers are not necessarily very accurate measures for innovation. In Japan and South Korea, 60 percent of patents held by government research institutes are never commercialized.[9]

Technology enterprises continue to face significant barriers to future growth. The most pressing of these challenges—the lack of investment capital, a low level of technological capability, an underdeveloped enterprise system, and inconsistent and contradictory government action—date back to the 1980s and have been constant sources of frustration to both S&T policymakers and high-technology entrepreneurs. The ability to address and resolve these issues will be critical to determining China's evolving technological capabilities.

Popular articles and scholarly analysts often cite the lack of capital as the biggest barrier to technological development in China. In a survey conducted by the State Council Development Research Center, 67% of the respondents listed "lack of funding" as the "biggest problem facing enterprise development."[10] Bank lending is the most important source of funding, but *minying* enterprises, still have difficulty securing loans, even with improved policy support. The central problem is that capital allocation is driven by political concerns and official edict, not market mechanisms. Fearing the social disturbances that may accompany unemployed workers, local officials prop up moribund state-owned enterprises through bank lending

Faced with these constraints, most nongovernmental firms rely on self-raised capital. A stock market for small technology firms has not been established yet and the threshold for listing is too high on the existent boards. High-tech companies are currently not allowed to issue bonds.

Closely related to the problem of capital is the question of technological capability. Despite rising technology exports, Chinese firms remain mainly involved in the production of products at the low and medium end of the technology scale. Chinese analysts note foreign firms hold the majority of the patents for the products China exports.

There have been some important changes in the role enterprises play as technology suppliers in the national innovation system. Still, questions remain about the relative role of smaller nongovernmental enterprises in the Chinese S&T system, especially in comparison to MNCs and the larger SOEs. In their survey of over 20,000 Chinese firms Jefferson et al find that "large-size" enterprises are significantly more likely to be a high R&D performer.[11] R&D intensity is closely related to firm size, profitability, and market concentration; it is also robustly associated with new product sales. State-owned enterprises bring into the country four-fifths of all technology products imported by Chinese-owned firms, and account for three-quarters of technology products exported by Chinese firms.[12] Many of the nongovernmental enterprises lack the resources to undertake the major commitments to research and development that characterize high-technology firms in more developed economies. In effect, while nongovernmental firms are a dynamic part of the economy, we should not expect that they will emerge anytime soon as the primary force driving Chinese economic and technological development.

In addition to technological weaknesses at the center of enterprises, many nongovernmental firms have failed to develop professional and standardized management techniques. Firms were often founded by charismatic scientists who lacked management skills. The strong personality required to battle bureaucratic opposition served small enterprises well in the initial stages of development, but as firms grew, the founders tended to "act as local despots," stifling the creativity of employees and running enterprises into the ground.[13]

Finally, the policy environment continues to suffer from at least three problems. First, the shift away from direct government control over primary actors in the S&T system is incomplete. State actors, for example, still control the investment process and government funds account for 80% of venture capital funds.[14]

Second, critical work remains to be done building an adequate legal environment that protects intellectual property rights and regulates private enterprise. The incomplete system for assigning, exercising and protecting intellectual property rights impedes not only inward technology transfers, but also discourages indigenous innovation. In addition, the legal framework governing venture capital, private business, and capital market regulation is still incomplete.

Third, decentralization, while spurring policy innovation, has also created redundancy and harmful competition. The rapid expansion of technology zones has left many asking if China actually needs so many zones and whether Silicon Valley can be duplicated.[15]

The Choices Ahead

As it considers future development, Beijing must find an economically efficient and politically tenable equilibrium that also accelerates technological innovation. Chinese policy makers are working to find optimal balances between domestic hardware and software production; between domestic and export markets; and between top down, state-directed industrial policy, and more indirect "innovation strategy."[16]

Between software and hardware

A quick contrast with India is instructive here. China is ahead of India along a number of dimensions relevant to software development, but it clearly lags in software production. For example from 1981 to 1995 China had 537 scientists/engineers in R&D per million against India's 151. China leads India in personal computers 3-1, and enjoys a 4-1 lead in Internet usage. Yet in 2001 India produced $8.4 billion of software, while China only produced $6.8 billion for its substantially larger economy. According to Li and Gao, using OECD data, "The percentage of hardware expenditure in China was significantly higher than that of India, 88% vs. 62%."[17] India shows a much greater expenditure on IT services (32%) vs. China at only (7.3%). Today in China, most consumers buy their software embedded in their hardware, not in separate packages.

Policymakers are clearly worried about China's failure to develop software firms. State Council Document 18 outlines incentives for the industry, and State Council Document Number 47, issued in 2002, identified a series of specific targets for the software industry: the development of a domestic software market valued at $30 billion, 20 large software companies with revenues of $1 billion RMB, 100 Chinese software brands, and software exports of $1-2 billion by 2005. The stated goal is Chinese companies should have 60% of domestic software market by 2010. Chinese planners are also trying to learn from the Indians. MOST began an initiative in November 2003 (the China Offshore Software Engineering Project) to develop outsourcing capabilities in a select number of Chinese software companies from regional software parks.

From domestic to export markets

Despite an IFC report that China will increase its share of global electronics production from 8% to 14% by 2005, foreign-invested firms dominate the export market. Chinese-owned firms manufacture ICT products mainly for the domestic market, and foreign-invested enterprises account for roughly two-thirds to four-fifths of China's electronics exports. This percentage has actually increased from 1996 to 2001.

Computer manufacturer Lenovo slowly turned their attention to foreign markets for exports during the beginning of the century, even though the firm only exported 7% of its production in 2003. The company announced its intention to increase exports to 25–30% of total sales by 2006. Few analysts believed Lenovo was going to meet that goal, and the purchase of IBM's PC division was motivated in part by the desire to overcome the Lenovo's weaknesses in international markets and achieve an instantly recognizable global brand.

From tech policy to innovation strategy

During the late 1990s Chinese decision makers began shifting their focus from more extensive to intensive development—and this move has been reflected in the proliferation of government policies more supportive of entrepreneurial and innovative activities. Policymakers now support all types of advanced enterprises—non-governmental, private, and small spin-offs—rather than just large state owned enterprises. This embrace of non-state actors also reflected important ideological changes made toward private enterprises.

Moreover, cuts in state agency manpower and mandate have inhibited the government's ability to select specific technologies for support. Now the government provides broad support to all domestic enterprises designated "high-technology." This support can take the form of access to low-interest credit lines, preference in procurement decisions, or other kinds of regulatory preference or relief, but is focused on the larger environment of innovation, not specific policy support. The third and final part of the strategy was to encourage the less tangible “software” forms of technology transfer (i.e. licenses, consultancy, etc.) rather than “hardware” in the form of equipment imports.

Innovation strategy is developed through funding support for S&T innovation by small and medium-sized enterprises; a tax exemption for all income from the transfer or development of new technologies and related consulting and technical services; a preferential 6-percent value-added tax rate for software products developed and produced in China; and complete VAT exemption and subsidized credit for high-tech exports. Chinese policymakers have also tried to make it easier to reward technologically inventive entrepreneurs for their contributions and have created venture capital companies and funds.

Conclusion

As the above discussion suggests, while there have been some notable success in the IT sector, system-wide barriers to greater innovative capability remain. The end result of twenty five years of reform has been a mosaic effect. Innovative capabilities differ by region, by sector and by firm. Technology enterprise formation has been most robust in regions with a strong scientific base, active local government support, and a large supply of S&T personnel. Innovative activity has clustered in the East, in Shanghai, Beijing, Shenzhen and Guangzhou.

The existence of pockets of excellence raises at least two important questions for this panel. First, what do individual success stories mean for the larger goals of S&T reform as well as creating a more dual use economy? Huawei is often used as an example of IT success and the possibility of “spin on.” But the relationship of Huawei to the larger stated goals of reform remains uncertain, if, not in some ways, in conflict.[18] The tools used to support Huawei may undermine more systemic innovation; government support dampens market pressures, increases the opportunities for rent seeking, and lowers the long-term competitiveness of enterprises. Government investment in firms, of both economic and political resources, makes officials less likely to allow the market alone to provide signals and ultimately to allow state-supported firms to fail.

On the policy side, 863 is a more flexible, peer reviewed government policy for critical technologies, but it still is a government policy for innovation. The same high levels of state attention and involvement that create the success within some areas may undermine the systemic changes needed for a larger, self-supporting system of “spin on.”

Given China’s immediate security concerns and a focus on a Taiwan scenario, the absence of more systemic innovation may not matter. The improvements that the commercial sector has fostered plus the purchase of weapons platforms from Russia has given the PLA increased capabilities across the Taiwan Strait.

Second, how will we know when “pockets of excellence” expand to more systemic change? In the past, much of the writing about the Chinese S&T system was about what was missing, and the reforms have been about filling in the boxes. R&D spending stagnated in the mid 1990s, for example, but now it is rising at a double-digit rate. The Chinese lacked a mechanism to move R&D out of universities, but now they encourage professors to strike out on their own, started an innovation fund for small technology-based firms, and built out National Engineering Centers.

At issue is no longer the absence or presence of organizations, or policy, capital but how well they work together and are they maximized to foster innovativeness. The focus is increasingly on "software" issues like management, individual initiative, risk, language, and integration skills. A recent story in the *New York Times* about higher education in China effectively sums up the issue: "China has pulled off one of the most remarkable expansions of higher education in modern times," but political restrictions on open debate hamper efforts to build truly great universities.[19]

Innovation is multidimensional and complex, and so cannot be measured solely based on some set of metrics. Rather we have to a clearer understanding of the "ecosystem" that innovation is located. The focus is more on intermediate outputs and relationships—between universities and industry, between military and commercial sector, between domestic and foreign producers.

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