GLOBALIZATION, STRUCTURAL CHANGE, AND THE ROLE OF GOVERNMENT IN CHINA'S SEARCH FOR A NATIONAL INNOVATION STRATEGY

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Interest in China's capacity for technological innovation has grown markedly in recent years, both within China and among foreign observers. China's rapid economic growth over the past two decades prompts questions about the extent to which future growth will it be driven by technology-based productivity gains. China's rise as a great trading nation raises questions about the changing composition of China's foreign trade and the extent to which will China be able to compete in international markets with knowledge-intensive, high value-added products. Chinese political leaders and defense planners, as well as foreign analysts, have become more concerned about the capacity for innovation in technologies of relevance to national security as the nature and implications of high technology warfare have become evident. And, the very high environmental costs associated with Chinese economic growth make the need for new, environmentally friendly technologies most pressing.

Underlying all these concerns is a recognition that scientific discovery and technological change, combined with economic globalization, are helping to create a new industrial revolution, promoting the emergence of what some have called the "knowledge economy." Chinese elites are highly sensitive to the fact that China missed out on many of the benefits of the last industrial revolution and want to be sure that China's place in the new one is assured. Success in scientific research and capabilities for indigenous technological innovation are rightly seen as essential for these objectives. As a result, efforts to strengthen China's national innovation system have intensified. Support for research and development is increasing in China, and new policies to encourage innovation are being promoted. These efforts, though, have to accommodate the strengths and weaknesses of domestic institutional legacies and the ongoing challenges and opportunities presented by the international environment - now more immediate as a result of China's entry into the WTO.

China's innovation strategy for the new century, still very much a work in progress, is usefully seen as an attempt navigate between these domestic and international realities. In a global economy that is increasingly characterized by transborder technological innovation, any effort to develop a *national* innovation strategy for a *national* system innovation that does conform to some degree to international trends, invites frustrating failures. At the same time, sovereign nation states cannot readily cede control over the terms of their technological futures to transnational agents who operate without institutionalized responsibilities for national security and economic well-being. Developing strategies for technological innovation, thus, remains a critical challenge for national governments, especially in developing countries.

In this chapter, I review the main elements of China's innovation strategy, assess their effectiveness, and explore the implications of globalization for the national innovation system. I will argue that the efforts of the Chinese state to develop an innovation strategy to promote economic well-being and national security have had mixed results. They are, nevertheless, of considerable interest to students of national innovation systems, especially in developing countries and transitional economies. The history of China's efforts to develop a national innovation system which is attuned to the challenges of the international economy is filled with important lessons about the pull of inherited institutional arrangements, the efficacy of state policies to promote development, and the unintended consequences of such policies. They suggest that the value of achieving the stated objectives of the official strategy must be weighed against a "serendipity factor" - the unplanned, unexpected behavioral changes which lead to a variety of institutional innovations of considerable relevance to innovative capacity. An effective strategy will recognize the consequences of serendipity and build upon them.[1]

[1] One of the best examples of the serendipity factor at work is the growth of a new entrepreneurship from within the technical community, discussed further below. Without always intending to do so, China's innovation strategy has helped open up space in civil society for the development of entrepreneurial activities, inadvertently providing assets and resources for innovators to exploit in the pursuit of their own "strategies" - from the bottom up. At the same time, many of these assets - technical and institutional - have also come from abroad, indicating again the importance of the international environment for building up the national innovation system.

Maintaining an effective strategy for innovation for the new century under the influence these domestic and international conditions has thus become a matter of considerable subtlety - one which tests the intellectual sophistication and political acumen of national policymakers. At its best, China's evolving innovation strategy reflects considerable learning from serendipity; at its worst, the strategy has tried to suppress it. Importantly, the pursuit of an adaptive innovation strategy has forced a re-examination of the role of government in the national innovation system and, more generally, has required that the terms of the state's relationship with civil society, and its orientation towards defining and protecting national sovereignty, be monitored and reviewed.

The Origins of the Strategy.

As with a select number of other large developing countries, such as post-independence India, the new government of China in 1949 declared a major commitment to the development of science and technology out of concerns for national security, economic progress, and national prestige. But - again, like India - in spite of the development of an extensive system of research and development institutions, and a very large population of scientists and engineers, this declarative commitment to science and technology had not after three decades led to a demonstrable capacity for technological innovation.

Until the early 1980s, China's "national system innovation" was derived from the model developed by the Soviet Union and it experienced many of the same generic problems found with the Soviet system.[2] It was also strongly influenced by national security programs - the Soviet Union and again like India - which led to the drain of material resources, and much of the best technical manpower, to major national defense missions with few benefits for the civilian economy. By the late1970s, the many problems associated with this system could no longer be ignored by Chinese decision-makers. By the mid-1980s, a far-reaching set of reforms in the science and technology system had been initiated - sometimes leading, sometimes following - the economic reforms that have unfolded over the past two decades. As the paper by Liu in this volume illustrates, these reforms have affected the policymaking system for science and

[2] For classic statements of these problems, see Berliner, 1976.

technology, the coordination mechanisms for research and development, approaches to funding mechanisms, and the sectoral distribution of effort among research performers.

The elements of the current, reform-era innovation strategy, thus, have evolved over the past two decades.[3] They began to appear under the leadership of Deng Xiaoping in 1978 in an effort to rebuild and reform the science and technology system following the disruptions of the Cultural Revolution years. By the 1990s, after more than a decade of reform policies, China's national political leadership had fallen into the hands of a generation of technically trained leaders whose education and life experiences convinced them that China's future depended critically on its capabilities in science and technology. Beginning in 1995, they introduced a new series of policies, responding to the successes and failures of earlier initiatives, policies which were intended to "accelerate" the progress of the nation's science and technology and strenthen the capacity for technological innovation.[4]

From S&T Policy to Innovation Strategy.

While reform policies were inspired by China's observations of capitalist market economies in the OECD countries, it is noteworthy that neither the science and technology system reforms, nor the economic reforms, were, at the outset, especially attentive to Western notions of innovation in any explicit fashion. However, by the 1990s, and especially in the last half of the decade, reform policies began to reflect the idea that a strategy for innovation would involve considerably more than reform of the S&T system, as assumed earlier in the reform period. By the early 1990s, Chinese policy analysts who had been carefully studying the experiences of the OECD countries became increasingly more sensitive to the nature of innovation in capitalist economies. By this time, China could also begin to assess the performance of its major state directed programs to promote research and upgrade industrial technology, which were introduced

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[3] These are explored in greater detail in Suttmeier and Cao, 1999. See also the paper by Liu in this volume.

[4] These include the 1995 "Decision on Accelerating S&T Progress," major endorsements for science, technology, and education at the 15th Party Congress in 1997, at the National People's Congress in 1999, and a more explicit focus on innovation at the 1999 National Conference on Innovation.

early in the 1980s, and the effects of the new entrepreneurship that had taken root in the economic landscape created by reform policies.

The latter was reflected in township in village enterprises which, with their market orientation, were considerably ahead of the state owned/plan coordinated enterprises (SOEs) in manifesting a demand for new technology (even while lacking the human- and machine- embodied technical resources found in SOEs). The new entrepreneurship was also evident in the rise of "new technology enterprises" (NTEs) which were appearing in Beijing's Zhongguancun and in other cities with large concentrations of research institutes and universities. Finally, after 1992, foreign direct investment in manufacturing began to expand significantly, bringing with it new plant and equipment, *and* a business culture of innovation which further illustrated the complex interrelationships of new knowledge, market demands, effective management, and clear entrepreneurial objectives which characterize successful capitalist firms.

Thus, by the mid-1990s, China's policymakers, and an increasingly cosmopolitan community of policy analysts, had opportunities to observe and analyze innovation-related phenomena in an industrial economy that had become remarkably differentiated over the course of a decade.[5] This permitted considerable policy learning during the 1990s and led eventually to the National Conference on Innovation in the summer of 1999, and to the "Decision on Encouraging Technological Innovation, Developing High-tech and Realizing Commercialization of New Technologies" made at the time by the Central Committee of the Communist Party and the State Council. The Conference reflected an appreciation that innovation, while involving science and technology, is a far more complex process than R&D itself, and that while national R&D policy is an important element in a strategy, it must be nested in a socio-economic context where risk-taking is rewarded and where social cooperation and inter-institutional coordination is highly developed.

The Main Elements of the Strategy

[5] One composed of state owned enterprises, township and village enterprises, "new technology enterprises," and foreign invested firms including those which were wholly foreign-owned and those which were involved with various forms of joint ventures with the three types of Chinese enterprises.

Science and Technology System Reforms. Of the many reforms in the science and technology system which have been initiated since the1980s, those which have affected the organization and funding of research are of greatest interest. Prior to the initiation of reforms, the science and technology system consisted of five sectors: a) the Chinese Academy of Sciences, with its more than 120 research institutes and professional staff of over 60,000; b) the institutions of higher education; c) a large number of specialized research institutes under industrial production ministries; d) institutes in the national defense sector; e) industry-specific institutes under local governments.

While rich in human and organizational resources, the performance of this system left much to be desired. It's research creativity had been severely attenuated by the radical politics of the Cultural Revolution, and its ability to serve the technological needs of the economy was severely constrained by the organizational separation of research from production. Under the old system, research objectives were set centrally, and funding flowed to research institutes as a matter of annual appropriations, with weak controls over quality and little relevance to social and economic needs. Links between research institutes and enterprises were weak. Enterprises themselves invested little in the creation of new knowledge since the division of labor within the production ministries (most of which, as a result of reform policies, have now been abolished) called for the centralization of research in ministerial institutes. Coordination between institutes and enterprises was a function of central planning rather than decentralized market exchanges. Research in institutions of higher education was seriously underdeveloped, with the result that the close relationship between advanced research and the development of high-level human resources was not well-established.

Reform policies have changed this system in notable ways. Changes in funding practices led to drastic cuts in regular budgetary appropriations and forced institutes to seek revenues through the sale of their knowledge. In conjunction with structural reforms, reforms in funding have moved research institutes much closer to the marketplace by allowing them to spin off commercial entities, to become companies themselves, or to become absorbed into industrial enterprises. The funding of basic research was put on a peer reviewed, project basis. The higher education sector has now become an important center of research and graduate education, but at the same time, has developed far-reaching business contacts through the establishment of university owned companies and through relations with Chinese and foreign industrial firms. Within the Chinese Academy of Sciences, institutes are being reformed and consolidated, staffing levels have been notably reduced, many institutes (as well as the Academy as a whole) have spun off their own companies, commercial linkages with domestic and foreign companies have been established, and a major investment is being made to create centers of excellence through the Academy's "Knowledge Innovation Program." In the ministerial and local government sectors, specialized freestanding institutes are being absorbed into industrial enterprises, or are being transformed into independent companies. Meanwhile, industrial enterprises have become far more important in the national innovation system.[6]

Thus, as a result of reform policies, the Chinese system has moved from one that was inspired by, and resembled, the old Soviet model, with prominence given to centralized research institutes, to one that takes its inspiration from the experience of the OECD countries, with corporations and universities playing central roles. The one exception to this trend is the continuing existence of the Chinese Academy of Sciences as a major player in the system.[7]

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[6] For discussions of the reform policies and their structural consequences, see Gu, 1999, and IDRC, 1997, and the paper by Liu in this volume.

[7] The role of the Academy in the reform era has been hotly debated. It is a major national resource, but it appears to fit oddly with the logic of the reform program, with its industry and university biases. When the reforms began, questions arose as to whether the Academy's traditional role as a research performer, with 120 plus institutes and a staff of close to 90,000 should be maintained. Some policy makers supported this traditional role, but others called for the maintenance of a research mission, but one which would be rationalized, more focused, and which would lead to considerable downsizing. A third position sought to move the Academy toward becoming an honorific institution, more like the U.S. National Academy of Sciences (NAS) or the U.K.'s Royal Society, with its research activities transferred to universities, ministerial institutes, or enterprises. The 1980s ended with a version of the second option. Under the rubric, "one academy, two systems" introduced by then CAS president, Zhou Guangzhao, CAS would continue as a center of frontier research and "public science" (e.g., that pertaining to agriculture and rural development, health, and the environment for which there was no direct market demand), while forcing most of the applied work to seek its future in the world of commerce. This then led to the growth of contract research, and more importantly, the formation of new CAS companies. The model has undergone further refinement under the leadership of President Lu Yongxiang, and with the generous funding of the "Knowledge Innovation Program," the Academy hopes to firmly establish its role as an indispensable center excellence for the national innovation system.

Increased R&D Expenditures and New Mechanisms for R&D Funding and Technology Diffusion. Reforms in the funding of R&D have reinforced structural reforms and reorganizations of the sort noted above. But, they have also led to a variety of new modalities of research expenditure, as exemplified by the establishment of the National Science Foundation of China (NSFC) in 1985 and the introduction of new national research programs including the National Key Technology Projects, and the national programs for high technology (“863") and basic research (“973").[8] A much larger share of China’s national expenditures on R&D is now made on a competitive, project proposal basis involving some form of peer review. China has sought to introduce a strong meritocractic foundation for the funding of its research programs with an eye towards building centers of excellence, as illustrated by its “Key Laboratories Development Program,” which now includes some 217 laboratory facilities across the country.[9]

A variety of other programs supporting technology development and diffusion activities include the Spark Program (begun in1986) to disseminate new technologies to China’s countryside, the National Industrial Demonstration Projects (1984), National Science and Technology Extension Projects (1990s), Engineering Technology Research Centers (1991), Industry-University-Research Partnership Program (1992), Productivity Centers (1993), the Technology Innovation Program (1996), Engineering Research Centers (1998), and the Torch Program (1988), discussed further below. A new Innovation Fund, initiated in 1999, is targeted at small and medium-sized enterprises.[10] In all of these research, innovation, and diffusion programs, central government expenditure continues to play a key role but, as discussed further below, contributions from industry and local governments are increasing. National R&D expenditures, reportedly, have been growing at an average annual rate of almost 18% over the past few years, and reached just over 1% of GDP in 2001, somewhat below the target of 1.5% set in 1995, but still a notable increase.[11]

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[8] For discussions of these, see Suttmeier and Cao, 1999, Dahlman and Aubert, 2001, Ch. 8.
[9] MOST, 2000, p. 20
[10] See, Dahlman and Aubert, 2001, Ch. 7, esp. p. 115.
[11] Statistics cited here are from the Ministry of Science and Technology. In recent years, specialists at the Ministry have endeavored to produce accurate, internationally comparable statistical indicators on S&T. However, Chinese statistics must still be used with care. Methodologies for collecting statistics on S&T are still evolving and incentives to distort or falsify data are

Exploiting Scientific Knowledge and Know-how in the International Environment. At the beginning of reform period, China's leaders recognized that China had fallen quite far behind international standards in its research and capacity for technological innovation, and that it could not overcome these deficiencies effectively on its own. A major objective in initiating the reform and "open door" policies of the post-Mao period, therefore, was to gain access to international science and foreign technologies. China therefore set about trying to tap into international science and technology through new policies to send students and scientists abroad for training, to import large quantities of technology embodied in equipment and machinery, and to encourage foreign investment and the technology transfers accompanying it. In doing so, China was able to economize on the costs of innovation (which were incurred by foreigners), and still introduce technologies which were novel to China.[12] As discussed further below, China's quest for foreign technology has been controversial with regard to its impact on innovative potential, and not all stakeholders in the innovation system are in agreement as to its wisdom.

Establishing a System to Protect Intellectual Property Rights, and Clarifying the Property Rights of Innovators. During the course of the reform period, a major conceptual shift occurred in Chinese thinking about the economic and legal status of technology. Under the old system, in keeping with its socialist principles, the products of research and development were considered to be public knowledge, freely available to all. With market reforms, and with changing attitudes towards the ownership of productive assets, Chinese thinking about useful knowledge has moved closer to that of capitalist systems. An early manifestation of this was the establishment of a patent office in 1985, a move that was intended to facilitate foreign trade and investment as well as to

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widespread. Cf., Rawski, 2002. The 1% of GNP figure for R&D expenditures does reflect a genuine growth in spending, but it is also a result of better data on the activities of smaller firms whose R&D activities were not captured in earlier statistical reports (personal communication).

[12] In this sense, Chinese national leaders, as well as the leaders of Chinese industrial enterprises have, in effect, been in agreement with the sentiments of a recent World Bank report that,

> "....innovation is to be understood as products, processes, practices that our new in the local context of China, down to the different regions and localities. In no way should innovation be perceived as referring only to brand new technologies in a global context. What matters for China's development is the concrete application and use of available technologies, not so much the development of new ones. At least for the time being." (Dahlman and Aubert, 2001, p. 101)

build an intellectual property regime for the Chinese economy itself. Although China's system of IPR protection is often regarded as more impressive on paper than in implementation, China nevertheless continues its efforts to strengthen its intellectual property protection regime, and has new obligations to do so now that it is a member of WTO.

Throughout the reform period, problems with the IPR system have affected Chinese innovators as well as foreign corporations. As structural reforms proceeded, and as the nature and volume of technical exchanges and transactions between generators and users of knowledge (research institutes, universities, enterprises, etc.) increased, the need for clarification of property rights, and of the value of those rights also increased, but often was not met. This issue finally began to receive serious policy attention at the end of the 1990s when the State Council gave its approval in 1999 to a new policy document, "Several Provisions on Promoting the Transformation of Scientific and Technological Achievements," which had been prepared by an inter-agency working group drawn from the Ministries of Science and Technology, Education, Personnel, and Finance, the People's Bank of China, the State Administration of Taxation, and the State Administration of Industry and Commerce.[13]

The "Provisions" make generous allowances for rewarding the discoverers of new, commercially useful knowledge, both in terms of direct compensation and in terms of the value of an idea as an equity contribution to a new enterprise. They also attempt to untangle the often complex ownership issues which arise when new high tech firms are spun off from state research institutes and universities, spell out more clearly the limits to collective claims on the benefits from an innovation, and make it easier for research personnel to move back and forth between the two worlds of government supported research facilities and business. As we shall see, below, with accession to WTO, China has also become more concerned about protecting the property rights claims of its own innovators, and plans to strengthen IPR protection is part of its response to the new challenges of WTO membership. As the Chinese innovation system continues on its trajectory of becoming more robust and creative, demands for stronger IPR protection from

[13] An English text of the "Provisions"can be found in "Provisions on Transforming S&T Results." Beijing, Xinhua, April 20, 1999. In FBI-CHI-1999-0428, April 29, 1999.

Chinese innovators themselves, as rights seekers, are likely to become more important in strengthening the intellectual property regime.[14]

Encouraging Venture Capital Funds. Like many other countries, China has come to appreciate the value of special funding mechanisms for high-risk, high return efforts at innovation. Experiments with venture financing began in the late 1980s, but did not result in an institutionalized venture capital mechanism due to the general underdevelopment of capital markets, a shortage of attractive high technology investment opportunities, a lax regulatory environment, and ethically questionable investment behavior. These conditions have yet to be fully overcome, with the result that a venture capital industry is still in its infancy. Nevertheless, the need for venture financing has increased, especially with the growth of new entrepreneurial companies, both publicly and privately owned, with the need for the privately owned being especially pressing.

To deal with the problems occasioned by an underdeveloped venture capital market, the State Council in June,1999, approved the trial initiation of a new one billion *yuan* ($US 120 million) Technology Innovation Fund which is focused on the needs of the roughly 70,000 companies which qualify as "small and medium sized technology-based firms." According to the regulations of the Fund, firms "...within every frame of ownership" will be eligible for support, with priority given to those with "...independent property rights, high technology, high value-added products, and those which are export oriented." In addition to the one billion *yuan* budgeted, the managers of the Fund hope to leverage additional monies from commercial banks through the subsidization of interest rates.[15] In addition to government efforts, interest in venture financing is picking up from both Chinese and overseas investors, in spite of many IPR and regulatory uncertainties. Reportedly, there were some 100 venture funds in existence at the end of 2000, with portfolios totaling $5.4 billion.[16]

[14] For an analysis of the role of domestic innovators as "rights seekers" in the construction of IPR regimes, see Schroeder, 2001.
[15] See, "Deng Nan Establishes Fund to Beef Up High-Tech Ventures," Beijing, Xinhua, June 25, 1999, In FBI-CHI-1999-0625.
[16] Sun, nd, p. 21.

Exploiting Spatial Characteristics of Innovative Activities. The reform era in China has as one of its signature features the establishment of special zones for economic activities. Among these, are a variety of special zones for research and innovation to support high technology development which have been sanctioned and encouraged by both central (n=53) and local governments. As with decision makers in other countries, Chinese policy makers have come to believe that the concentration of high technology industry, and research and development activities, in special locations can lead to positive externalities and distinctive cultures of innovation. As noted above, one of China's special technology encouragement programs, the Torch Program, was initiated in 1988. Torch has been focused principally on the transfer of research results to production through the establishment of incubator services for small and medium-sized enterprises in high technology zones, and in this sense, has reinforced moves toward spatial concentration. As discussed in the paper by Wang and Tong, industrial clustering is occurring in a variety of industries in different places around China, which produces regionally distinctive innovation dynamics.[17]

In addition to the encouragement of special zones, there has also been an increase in support for innovative activities by local (provincial and sub-provincial) governments. Because of China's large size, and the legacy of past defense and industrial policies, technical assets for innovation are concentrated in more locations around the country than one might assume. While Beijing, and to a lesser extent Shanghai, do represent the greatest concentration of technical manpower, research institutes, and universities, a number of other cities - Guangzhou, Nanjing, Hefei, Wuhan, Chongqing, Chengdu, Xian, Tianjin, Shenyang, Dalian, Changchun, Harbin - are also centers of research and innovation activities. In recent years, local government's have become more active in developing these resources. Expenditures on science and technology by local governments have grown more rapidly than that of the central government, over the course of the 1990s albeit from a much smaller base. By1999, local governments had accounted for almost 37 percent of the national expenditure on science and technology, up from 28 percent in 1991. However, spending on science and technology activities by local governments was still only slightly more than two percent of local government expenditures in 1999. This percentage is likely

[17] See also, Dahlman and Aubert, 2001, pp. 115-118.

to increase as many locations begin to move towards the slightly more than four percent figure which characterizes national government effort. ([MOST, 2000 #318], pp. 34-35). Again, size, local factor endowments and market conditions, the legacy of past policies, and differential commitments of local governments has led to considerable regional diversity in these "local innovation systems" which are becoming more important for the national innovation strategy.

Issues Associated with the Strategy

We can see that China has pursued a multifaceted and aggressive strategy to enhance its innovative capabilities. By some measures, the strategy has had considerable success. The technological level of the Chinese economy has been raised notably over the past 20 years, the higher education system is producing large numbers of technical personnel, Chinese scientists and engineers are publishing an increasing number of papers in internationally recognized journals, and patenting activity is increasing.[18]

And yet, Chinese analysts and foreign observers of Chinese innovation performance, alike, can readily point to major disappointments in the record, and to weaknesses and deficiencies in China's national innovation system.[19] Thus, while more advanced technologies are evident in the economy, the greater share of these has come from importing technology from abroad. There is a widespread belief that China's assimilation of this imported technology has been disappointing, and in the views of many in the research community, dependence on foreign technology has worked against the further development and maturation of the domestic innovation system. While special science and technology zones have contributed to the development of high technology industry, these contributions have tended to come chiefly from foreign invested firms. For sceptics, the preferential policies of the zones have done more to promote rent seeking than innovation.

While R&D support through targeted national programs has increased, and has led to significant research progress, the wisdom of these programs has also been questioned. They are typically driven from the top down and don't always reflect investigator judgments as to what is important science. Personal relationships are said to compromise the application of meritocractic

[18] These trends, and limitations to them, are documented in MOST, 2000.
[19] A good summary of these dissents can be found in Dahlman and Aubert, 2001, esp. Chs. 7-9.

principles in the distribution of research funding, and industrial enterprises have been largely excluded from these programs at both the design and implementation stages (often, because they do not have the talent to compete in them), with the result that they reinforce the separation of research and production and, thus, are at odds with the spirit of the S&T structural reform program. In assessing these programs, a World Bank team has noted that,

> "The number of patents obtained by projects funded by Program 863 is on the order of 700 over the period 1986-98, approximately half the number obtained by basic research projects supported through the National Natural Science Foundation - for which the government spent about one-third as much money over the twelve years."[20]

[20] Dahlman and Aubert, 2001, p 136, fn. 6.

Similarly, while large numbers of technically trained personnel are being produced by the higher education system, there is considerable concern that careers in science and engineering have become less lustrous than they once were for top students, and that the best and brightest of those who do enter science and engineering are lost to the brain drain (both the overseas brain drain and the "internal" drain of talent to foreign firms in China). In spite of the growing numbers of publications from Chinese investigators, their lack of creativity reflects deep seated problems in the higher education system and weaknesses in the design and implementation of the national programs.[21] National spending for R&D, while increasing steadily over the course of the 1990s, is still - as a percentage of GNP - notably below the levels of the industrialized countries, and the per capita level of support for researchers remains quite low.

Weaknesses in China's system of innovation are also associated with a series of imperfections in the partially reformed political-economic system, and from problems of policy inconsistency. These range from confused ownership and intellectual property rights arrangements, weak incentives for risk taking, lack of transparency in financial markets, problems with corporate governance, a generalized lack of trust and social capital in the business culture, and inappropriate roles of critical institutions - including government agencies, universities, and enterprises - in the national innovation system. Misguided regulations by government work against other policies designed to aid innovators.[22] Often - in conflict with the policy intentions expressed at the 1999 National Innovation Conference - these regulatory policies are advanced in ways that benefit the interests of established SOEs and work against the interests of small entrepreneurial firms outside the state sector, especially as they seek to qualify and compete for state development projects and get access to get bank financing and (Brizendine, 2002, p. 28).

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[21] For problems with the Chinese R&D system, as seen by some of China's leading young scientists, see Cao and Suttmeier, 2001. For a recent critique of the creativity and preparation of Chinese software engineers and computer programmers, see Brizendine, 2002.

[22] Commenting on the software industry, for instance, Thomas Brizendine has recently observed that the government "...... often makes decisions in areas from financial system practices and regulations, to educational system development, to Internet supervision and control, that restrict access to funds or technologies and that tend to restrict the industry's natural growth and progress." (Brizendine, 2002, p. 28).

Similarly, some observers believe that Chinese universities have acquired a distorted role in the NIS as a result of reform pressures, as Xue's paper indicates. While dynamic industry-university ties exist where few existed before, universities may have defined their missions in overly commercial terms. The ties with industry are too intimate, and the commitment to fostering of creativity, to educational excellence, and to the disinterested search for knowledge, which characterize the world's great universities, has been compromised by under funding, and the consequent need for active commercial engagement.[23]

The Enterprise Problem

A major objective of China's S&T reform strategy has been to place the industrial enterprise - rather than the free-standing "public" research institute - more clearly at the center of the national innovation system. Again, the inspiration from the OECD countries is evident; corporations in capitalist economies have become leaders in the funding and performance of R&D, and serve as the institutional locus for bringing together the diverse elements - technology, finance, marketing, risk taking, etc. - for converting inventions, discoveries, and original ideas in management into commercially viable innovations.

Though their capacity for innovation has increased, many questions remain about the ability of the Chinese enterprise to play the dynamic role in technological innovation which companies in capitalist economies have come to play. Table 1 illustrates the effects of national policy to put the enterprise in a more central position by increasing its role in R&D. The switch in the relative share of effort from R&D institutes to enterprises over the course of the 1990s is somewhat reminiscent of a similar shift which occurred in Korea at an earlier period. Yet, while the enterprise sector's role in the performance of research has increased, its role as a source of funds is less clear; in 1999, for instance, the share of the nation's R&D funded by "large and medium-sized" enterprises was only 37 percent. This figure does not include the many smaller enterprises which have developed outside the state sector.

[23] For a discussion of efforts to reverse these trends, see Lawrence, 2001.

Table 1. Percentage of R&D Expenditures by Performing Sector in Selected Countries				
	Enterprise	R&D Institute	University	Other
China (2000)	60.3	28.8	8.6	2.3
China (1999)	49.6	38.5	9.3	2.6
China (1996)	36.8	41.1	13	9
U.S. (1998)	75.2	7.9	14.0	3.0
Japan (1998)	72.7	14.3	13.0	
France (1997)	61.6	19.9	17.2	1.3
Russia (1998)	68.9	25.8	5.2	0.1
Korea (1998)	70.3	17.4	11.2	1.1

Source: Ministry of Science and Technology. China's Science and Technology Statistics: Databook, 1997, 2000, 2001.

When China entered the reform period, industrial enterprises typically lacked the incentives to undertake the risks of innovation. As parts of industrial ministries (or the industrial bureaus of local governments) which had their own centralized R&D and design institutes to serve the innovative needs of enterprises throughout the ministry, Chinese enterprises were also structured inappropriately for innovative tasks. Reform policies have been directed at both of these deficiencies. Marketization and the growth of enterprise autonomy have altered the incentives picture notably; many Chinese enterprises have come to show an interest in new technology in ways one would expect from companies facing market competition.[24] They have

[24] But, they face crosscutting pressures of a reform environment where efficiency and profit-making objectives can some times be in conflict, and where the availability of new technologies in the environment create conditions of technological turbulence. When the pursuit of

clearly come to increase expenditures on innovative activities and on new technology acquisitions. Gradually, they are coming to develop "in-house" capabilities for innovation, including the building of their own R&D capabilities, as reflected in Table 1.[25]

The changing nature of attitudes towards technology acquisition among Chinese enterprises is illustrated in Table 2. Of particular note is the fact that in 1999, for the first time, they began spending more on their own R&D than on imported technology. The growth of interest in domestically developed technologies during the 1990s is also noteworthy.[26]

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profit is not always compatible with the pursuit of efficiency, enterprise commitments to innovation and to "good practice" diverge. Recent empirical work by Howard Davies indicates that Chinese firms face,

> "... a complex set of relationships between the process of reform, institutional change and enterprise commitment to technology development. Different aspects of reform influence firms in different ways. As the firms becomes more marketized, their commitment to innovation is increased by the greater emphasis on efficiency, but reduced by the greater pressure for immediate profit. The same pressure to make profit increases their commitment to good practice. As government opens markets to more intense competition, commitment to good practice is increased but commitment to innovation is reduced as enterprises have less slack at their disposal. Increased technological turbulence enhances the commitment to innovation, but reduces commitment to best practice. High technology settings, in which research institutes and universities produce appropriable new technologies, enhance commitment to innovation but have no impact on commitment to good practice." Davies, 2001, pp. 37-38.

Davies goes on to observe that

> ".... the most effective way for the Chinese government to improve enterprise commitment to innovation is to increase the range of 'high technology opportunities' facing them, and to encourage them to become more efficient while not forcing them into intensely competitive environments where short-term profit considerations become paramount.."(p.37)

He also suggests that at this stage of Chinese development, a stronger IPR regime may not be desirable, since "....tightening the regime of appropriability would have an adverse effect on commitment to innovation." (p. 37).

[25] In 1999, approximately 32% of China's "large and medium-sized" enterprises had their institutions for technology development. MOST, 2000, p. 49.

[26] In a recent paper, Sun Yifei has examined innovation activities in Chinese enterprises in terms of patent applications, patents granted, and new product sales. Sun, 2002. He finds that in house R&D expenditures explain enterprise patenting results, but expenditure on imported technology is more closely associated with new product sales. This is consistent with the author's observations from the mid-1990s as reported in Suttmeier, 1997. Interestingly, Sun goes on to observe that,

Table 2. Technology Acquisition Expenditures of Large and Medium-sized Enterprises, 1991-1999 (100 million yuan)									
	1991	1992	1993	1994	1995	1996	1997	1998	1999
R&D Expenditures	58.6	76.1	95.2	122.0	141.7	160.5	188.3	197.1	249.9
Expenditures on Buying Foreign Technologies	90.2	116.1	159.2	266.7	360.9	322.1	236.5	214.9	207.6
Expenditures on buying domestic technologies	3.7	--------	4.7	13.2	25.5	25.8	14.6	18.2	13.8

Source: MOST, 2000, p. 53.

Meanwhile, most central and local government research institutes in the areas of industrial technology have been absorbed into enterprises as R&D centers, have become independent companies themselves (sometimes absorbing the production facilities of factories), been transformed into consulting and/or technical services companies, or in some cases, have merged

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"Such results may indicate that in-house R&D labs are effective in creating new technologies, but fail to convert such technological advantages to commercial success. In other words, efforts in in-house labs have not been successfully linked with other parts of the business....As such, in-house R&D labs for industrial enterprises share similar problems with other parts of China's innovation system, [such as] state R&D institutes and universities, where innovative activities are not well linked with market demands." (pp., 16-17).

I am grateful to Professor Sun for sharing this paper with me.

with academic institutions.[27] Since 1999, new policies have mandated these changes at both the national and local levels, focusing initially on 242 important institutes under the central government (MOST, 2000, p. 45). These reorganizations do address long-standing problems with the design of the old innovation system, but they do not guarantee a smooth integration of research with production, absent further organizational and managerial changes within enterprises.[28]

The promotion of high technology industry has been a major policy objective of China, especially over the past decade. In1999, the high technology sector for the first time exceeded 10 percent of the total value of the nation's manufacturing (MOST, 2000. p. 81). It has outperformed the rest of the industrial economy in the growth of labor productivity and, in the 1993-1999 period, its rate of growth in value added was notably higher (almost 20%) than in the manufacturing sector generally (7 percent) (MOST, 2000. p. 82). As one would expect, the R&D intensity[29] of the high technology sector was higher than that of the rest of the economy. But, when compared with that of the industrialized countries, as seen in Table 3, it is modest.

Table 3. R&D Intensities Of Manufacturing And High Technology Industries In Selected Countries (%)

	China	U.S.	Japan	France	Italy	UK	Canada
	1999	1996	1996	1996	1997	1997	1997

[27] Cf., Suttmeier, 1997, and IDRC, 1997.
[28] Cf., note 26.
[29] Here, R&D intensity is understood to be the ratio R&D expenditures to value added.

Table 3. R&D Intensities Of Manufacturing And High Technology Industries In Selected Countries (%)							
All manufacturing industries	2.3	8.9	7.8	6.6	2.8	5.5	3.7
High technology industries	3.6	27.9	19.1	27.8	21.8	20.0	25.5
Aerospace	9.4	38.7	21.2	32.2	25.1	18.1	20.2
Computer & office equipment	3.2	43.1	27.4	9.7	12.5	4.8	26.6
Electronics & communications	3.6	21.3	15.5	32.1	25.5	13.7	33.3
Drugs & medicines	2.2	21.1	21.2	28.6	19.3	32.5	17.1

Source: MOST, 2000. p 86.

Table 3 illustrates that Chinese industry, especially high technology industry, has a long way to go before it can begin to challenge the firms in the industrialized countries on this important measure of innovative activity. Chinese enterprises lacked the resources to undertake the major commitments to research and development which characterize high technology firms in the OECD countries, a condition often associated with firm size. Chinese policymakers have thus sought to promote the formation of larger, more capable corporations through an industrial policy of enterprise consolidation and preferences, especially in strategic or “pillar” industries.[30] A recent assessment of the effectiveness of this policy by Peter Nolan acknowledges some policy success,[31] but concludes that when one examines the prospects for Chinese companies in such high priority industries as aerospace, pharmaceuticals, complex electrical equipment, oil and petrochemicals, car assembly, automobile components, steel, and mining, China’s industrial policy has failed to

[30] Chinese perceptions of Japanese and Korean experiences with industrial structure have been especially influential in this regard.

[31] Including respectable growth rates for many Chinese firms, successful reforms in their operational mechanisms, steep learning curves with regard to technology and management, and successful partnering with multinational corporations.

create internationally competitive firms; "....not one of China's leading enterprises had become a globally competitive giant corporation, with a global market, a global brand, and a global procurement system."[Nolan, 2002 #316], p. 130.

While some might argue that the prospects for Chinese companies may not be as bleak as Nolan's analysis would imply, nevertheless, the combination of internal and external factors identified by Nolan, makes the achievement of the needed size and organizational effectiveness for world leadership an elusive goal.[32] An innovation strategy built around the idea of creating large, globally competitive companies, thus, may be misdirected, at least in the short run. How does one create such companies, for instance, when the combined R&D budgets of only three or four of the world's larger multinationals represent a greater commitment of resources to innovation than China's entire national R&D expenditure?[33]

The International Dimension.

From the start of the reform era, the international environment has figured prominently in China's strategy for technological development. Not only has China acquired vast amounts of foreign technology over the past 20 years, it has also availed itself of opportunities for advanced education, and for scientific and technological cooperation with universities, research institutes, and private corporations abroad. It has exploited the resources of the World Bank and other international organizations to strengthen Chinese institutions for education and research.[34] China

[32] These include such domestic factors as policy inconsistency, weaknesses in the structure of Chinese firms, the fact that China is still a relatively poor country, local protectionism, legacies from the planned economy, inappropriate diversification bureaucratic corruption, and an ideological commitment to state ownership. The external factors identified by Nolan are related to the power and capabilities of large multinational corporations and to global economic liberalization which benefits MNCs. Nolan, 2002, pp. 131-133.

[33] In the auto industry, for instance, the annual expenditures for R&D in 1998 for Ford, GM, and Daimler-Chrysler amounted to $US 21 billion Nolan, 2002, p. 127. This dwarfed the $US 4.5 billion spent in China in 1995 for the country as a whole, and is still more than the $20 billion Chinese outlay when Chinese expenditures are expressed in PPP dollars. See, Dahlman and Aubert, 2001, p. 121.

[34] We should recall that China's first loan after joining the World Bank was one to upgrade university laboratories. This was followed by other lending projects for higher education, and by

has also attempted to take advantage of overseas ethnic Chinese professional communities to facilitate cooperative projects and to acquire high-quality scientific and technological advice.

While it is inconceivable that Chinese science and technology could have progressed as far as it has in 20 years without this aggressive "open door" policy, China's involvement with the international environment has not been without problems and controversy. For instance, although China is now one of the most successful countries in the world in attracting foreign investment - with foreign invested enterprises accounting for as much as 45 percent of Chinese exports in 1998 - and although foreign investment has been an important source of technological learning, a number of weaknesses in Chinese management of foreign investment have been identified. These include significant disincentives, if not outright barriers, to foreign investment in the IT-intensive service sector, under performance in attracting investment from companies outside of the Chinese cultural sphere, especially from Japan and Europe, and a failure to address the uneven geographical distribution of foreign investment.[35]

In China's approaches to the acquisition of foreign technology, it has tended to rely on the importation of technology embodied in equipment, and on technologies flowing into the country through foreign invested firms. It has relied considerably less on the procurement of disembodied technology through licensing, and has been reluctant to pay for training and technical assistance which might accompany equipment purchases. As seen in Table 4, China's approach to the licensing of technology is more like that of India than of the industrialized countries. It also differs notably from the experiences of Brazil and Korea (and from Japan in earlier periods).

Table 4. Licensing Fees by Country (%) (2000)

	China	India	France	U.S.	U.K.	Korea	Brazil	Japan

loans to support the "key laboratory" project and the establishment of engineering research centers, noted above.

[35] The discussion which follows is based on Dahlman and Aubert, 2001, Ch.9. Some of these problems may be ameliorated as a result of China's accession to WTO, the strengthening of the legal system it is expected to produce, and the launching of the "Western development" program for the interior provinces during the 10th Five Year Plan period, which is expected to help attract foreign investment to neglected regions.

Table 4. Licensing Fees by Country (%) (2000)								
As share of GDP	0.08	0.07	0.16	0.15	0.44	0.65	0.17	0.23
As share of merchandise imports	0.48	0.71	0.79	1.25	1.97	2.22	2.48	3.17

Source: Dahlman and Aubert, 2001, p. 148.

China has signed formal agreements for international cooperation in science and technology with many other governments, and with international organizations, universities, professional organizations and foreign companies. Yet, it spends only 1.5 % of total R&D expenditures on international cooperation, considerably less than other countries with large science programs.[36] Devising a more successful strategy for international cooperation is a challenge for China given the growing role in international scientific and technological cooperation of private corporations, with their concerns for protecting proprietary knowledge, and in light of changing perceptions of China as a potential economic competitor and/or security threat.

No discussion of Chinese efforts to exploit the technical resources available in the international environment would be complete without mention of efforts to build ties with Chinese scientists and engineers abroad. A central concern, here, is to manage the brain drain that China has experienced as a result of more than 300,000 science and engineering students going abroad for education over the past 20 years, with only slightly more than 100,000 returning. A variety of programs have been established to encourage this talent to return, and there has been some success.[37] Nevertheless, for economic, political, and professional reasons, large numbers of professionals have chosen to remain abroad and build lives and careers outside of China, and China has yet to devise an effective strategy to induce them to return. On the other hand, scientific and technological cooperation with Taiwan has increased in spite of the existence of enduring political differences. Investment from Taiwan in high technology has become an important

[36] Dahlman and Aubert, 2001. p. 150.
[37] See, Cao and Suttmeier, 2001.

vehicle for transferring technologies and management practices which worked well in a Chinese cultural context on Taiwan to the mainland. Cooperation between Taiwan invested firms and mainland R&D centers constitutes an especially interesting resource for the national innovation strategy.

Managing Globalization

For most of the reform period, the Chinese government has actively encouraged the acquisition of foreign technology and has provided generous resources to that end. Chinese enterprises took advantage of those resources and, typically, developed a strong preference for foreign technology to address their technological needs. As enterprise autonomy increased, and enterprises had to find their own resources for technological enhancement, the preference for foreign technology remained - to the extent that the enterprise could afford it. It is only late in the 1990s that we begin to see Chinese enterprises adopting a more balanced approach to technology acquisition, with more attention being given to indigenous sourcing (in-house, or from domestic R&D institutes or universities), as seen in Table 2. Typically, though, this preference for foreign technology was not matched by successful technology assimilation programs, and often came at the expense of the domestic research system. Thus, with the enormous sums spent on foreign technology, China may have developed a technological dependency on the latter which works against the long term goals of the innovation strategy.

The globalization of science and technology has increased the risk of the Chinese research system becoming incorporated into the global networks of multinational corporations, or subordinate to the innovation systems of the advanced countries. Chinese observers who hold this view fear that Chinese technologies cannot compete with those of the major international players and, increasingly, Chinese technical talent is being drained into institutions which are controlled by foreigners.[38] China's national system of innovation seemingly is becoming integrated with globalized networks of technology and scientific activities on someone else's terms, thus making control over the national innovation strategy more difficult and the prospect for a strong,

[38] For a recent discussion of these issues as they pertain to the electronics industry, see Simon, 2001.

autonomous innovation system of the sort favored by China's technological nationalists and defense planners less likely. Opportunities to capture value from participation in the global networks can be enhanced by an effective national strategy, but control over objectives and means for such a strategy will have to be shared with others. China's accession to WTO increases the challenge of devising an innovation strategy which both conforms to global realities and serves national interests.[39]

China has been preparing for WTO membership on many fronts in the belief that accession will carry a series of obligations that will both put enormous new pressures on the Chinese economy, *and* strengthen the institutions necessary to operate a market economy under the terms of the global trading regime. Some of these developments, especially the strengthening of China's IPR regime, and the legal system more generally, are likely to be quite beneficial for China's innovation capacity over the long run. Chinese leaders have also taken a position that consistent improvements in the operation of the national innovation system, and the active development of a national technology policy, will be necessary for China to benefit from WTO membership.

To this end, the government has begun to devise new programs in response to accession. For instance, the Ministry of Science and Technology has recently concluded a series of meetings which explored China's options. Reflected in discussions from these meetings is the recognition that China has become one of the more important manufacturing bases in the global economy, and that its ability to exploit its position in the international division of labor will require ongoing technological innovation, including the application of new technologies to traditional industries. On the other hand, China also wants to become a leader in knowledge-based industries by leapfroging into leading roles in emerging new technologies. The priorities for science and technology in the 10th Plan (2000-2005) address these objectives and reflect the new reality of WTO membership. According to science minister Xu Guanhua, China will make significant

[39] For instance, there is some fear that WTO membership will exacerbate the internal brain drain of technical talent away from Chinese enterprises t foreign firms. See, Wu Zhong. "State Firms' Brain-drain Acute Since WTO Entry."
http://www.hk-imail.com/inews/public/article_v.cfm?articleid=31509&intcatid=2.

increases in the funding of twelve areas of strategically important technology.[40] It will pay particular attention to the need to strengthen IPR protection for Chinese innovators, and incorporate a sharper focus on the management of intellectual property for China's benefit in national research and development programs. China realizes that in the global knowledge economy there is a fierce competition for intellectual talent, and it will therefore redouble efforts to attract back to China the scientists and engineers lost to the brain drain. Finally, Xu indicates that China will pay much more attention to the development of its own technical standards in such fields as IT and biotechnology by building on distinctive features of the Chinese language, the Chinese business and administrative environments as these pertain to e-commerce and e-administration, and the Chinese biological inheritance and pharmacopeia.[41]

Such initiatives raise questions as to both their efficacy, and compatibility with WTO provisions. It is too soon to render confident judgments on these two questions except to note that in light of the problems in the innovation system noted above, these measures are positive steps towards enhancing the capabilities of the system even if they are unlikely to change Chinese competitiveness in high value added industries in the short-term. As for consistency with WTO norms, targeted national research programs, and the use of technical standards in industrial policy, have both been controversial within the GATT/WTO framework in the past. In the short run, these aspects of the Chinese strategy may not produce discord (although, standards for genetically

[40] "The ministry will concentrate on super scale integrated circuits and computer software, information security systems, e_ administration and e_finance, functional gene_chips and bio_chips, electric automobiles, magnetic levitation trains, new medicines and modernization of production
of traditional Chinese medicines, intensive processing of farm produce, dairy product manufacturing, food security, water_conservation farming, water pollution control and the establishment of key technical standards."Beijing Xinhua in English, 09 Jan 02. In, FBIS_CHI_2002_0109.

[41] See, "Xu Guanhua on PRC's S&T Strategies To Cope With WTO." Beijing Zhongguo Xinwen She, January 9, 2002. Translated in FBIS_CHI_2002_0109; "Chinese S&T Minister on Plans to Launch Research into 12 Key Technologies."Beijing Xinhua in English, January 9, 2002. In FBIS_CHI_2002_0109; and "China's S&T Minister Xu Guanhua Says PRC To Introduce IT in Traditional Industries." Beijing Xinhua Hong Kong Service, January 10, 2000. Translated in FBIS_CHI_2002_0110.

modified food products have already come into dispute in U.S.-China trade dealings, and are likely to be a source of controversy for some time) as long as China's trading partners do not feel aggrieved by them. However, should these measures enable Chinese firms to begin to claim significant market share in the global marketplace - or deny significant market opportunities in China to foreign firms - they will come under much closer scrutiny by China's trading partners, and complaints to the WTO will be more likely. China's interest in developing its own technical standards is an interesting response to globalization, but is one which also requires deft execution in a global economy where established standards already provide a framework for successful economic activities. It also illustrates many of the dilemmas faced by developing countries seeking to upgrade their position in the international division of labor through a national innovation strategy.

In a recent paper on China's telecom manufacturing industry, Zixiang Tan has argued that the structure and standards of the global telecommunications and information technology industries both work against Chinese technological aspirations and provide a useful architecture for Chinese enterprises to establish production niches for successful competition with multinational corporations in selective segments of domestic and overseas markets. Borrowing from the work of Michael Borrus and John Zysman on "Wintelism" (the Microsoft Windows/Intel standards) and its influence on the development of "cross-national production networks" (CPNs) (in which an industry's value chain is "disintegrated" "...into constituent functions that can be contracted out to independent producers wherever those companies are located in the global economy" (Borrus and Zysman, 1997; cited in Tan, 2001)), Tan notes that new business opportunities have developed in China, at various stages of the value chain, which often involve complex, two-way outsourcing made possible by the open standards. He cites the case of Huawei, one of China's largest telecom equipment makers, which competes successfully in central switching equipment in the Chinese market as well as in 40 other countries. Huawei, like other major Chinese telecom manufacturers (Cf., Shen, 1999), is not without technological assets and a tradition of innovation, but its weaknesses in complementary technologies limits its competitiveness in parts of the value chain. Thus, while Huawei has its own proprietary designs for application-specific ICs (ASICs), it lacks the ability to produce these itself. Nor can it find other Chinese producers with the needed capability. It therefore contracts out to major partners in United States and Europe for these high-end components (Tan, 2001).

Tan's discussion illustrates that, within established standards, many Chinese firms that possess capabilities for technological innovation are able to thrive in a global environment characterized by cross national production networks if they understand where their competitive advantage is relative to the production value chain. This is a picture of increasing interdependencies where multinational enterprises outsource a variety of work to Chinese enterprises, but where Chinese firms, in turn, seek complementary assets from technological leaders when their own capabilities have been reached. Tan's findings are consistent with the thesis developed in the paper by Gu and Steinmueller which stresses the value of China's accumulated scientific and technological resources which can be "unlocked" and made available for an "innovative recombination of technological capabilities" as new market opportunities, institutional forms, and complementary technological assets appear in the environment (Cf., Shen, 1999). This situation raises interesting challenges for government standard setting policy.

On one hand, the standards and industrial organization in the international economy provide a framework which permits entrepreneurial and technologically progressive Chinese firms to capture value from the global economy. Efforts by the Chinese government to establish distinctive standards in the interest of promoting Chinese firms thus run the risk of making Chinese enterprises less adaptable to that architecture; a sensible government strategy under such circumstances might therefore be one of neutrality - to "do no harm." On the other hand, the success of companies like Huawei lies mainly in areas of more mature technology and less value added production. Industry leadership remains with those companies in the advanced economies which set the pace for new technologies and products. These are the products which are imported into China to meet high-end demand, with profits repatriated out of China, in a market segment in which it is very difficult for Chinese companies to compete. The standard East Asian industrial policy response under such circumstances is that - absent government intervention, the inherited international hierarchy of technological and economic leadership will remain unchanged. However, as the discussion above suggests, government intervention is no guarantee that China can move up in this hierarchy, and inappropriate intervention could seal China's subordinate position for some time. Thus, defining a proper role for government has become an important challenge to the strategy.

Conclusion - Strategy and the State

China's efforts to develop a national innovation strategy is an especially interesting case for those seeking to better understand the development and performance of national systems of innovation - especially in developing countries and transitional economies. The Chinese case is one characterized by a long-standing commitment to scientific and technological development going back to the founding of the People's Republic, to the Republican period before that, and indeed, to the 19^{th}-century. These efforts at developing science were frequently derailed by foreign invasions, civil war, and radical politics. Nevertheless, under the post-1949 socialist formula, China was able to build up a substantial system of institutions staffed by a very large number of scientists and engineers - an impressive feat for a poor, developing country.

This was not, however, a system that was in tune with modern conceptions of innovation, most of which have their roots in capitalist economies. A critical element of China's innovation strategy, therefore, has been the extensive reforms discussed above, reforms which in policies and organizational arrangements, have sought to change the inherited science and technology system into one which more clearly resembles those found in capitalist countries. As these reforms have unfolded, they have produced a variety of intended and unintended consequences which have both been supportive of reform objectives, and corrosive of them. These successes and failures have provided opportunities to learn more about what innovation is all about and, from this learning, the strategy has been modified and adapted to new realities. As this "reform-learning-adaptation cycle" has progressed, one of the more interesting challenges that has emerged is that of defining an appropriate role for the state in the national innovation system, one that facilitates - rather than discourages - "the innovative recombination of technological capabilities" discussed by Gu and Steinmueller.

The Chinese case also illustrates the challenges of developing a national innovation strategy that meshes with the contemporary realities of globalization. Few developing countries are as well-suited as China to confront the challenges of globalization and turn them to their advantage. The Chinese state - in spite of its problems - is sufficiently robust to define and enforce the terms of its relationships with the international economy. China brings to its interactions with the outside world not only abundant inexpensive labor and a large market, but also a complex and diversified industrial structure. *And*, few developing countries possess the large pool of technical manpower and institutional infrastructure for science and technology that China does.

That said, we can see from the above discussion that China faces many difficulties before it can assume a position of global leadership in scientific research and technological innovation. Like other developing countries, it is faced with the interesting challenge of capturing value from globalization through the strategic deployment of its technical resources, both by building up its national capabilities through its own efforts, and by making the technology, financial resources, and management skills of its international partners serve its long-term interests. Arguably, China has already made notable progress in making this strategy work, but it still has a long way to go. In negotiating through this future, it will be necessary for it to maintain a clear understanding of what the changing challenges of innovation are all about, and be able to adjust its strategy in response to the interactive effects of dynamic technological change, changes in the institutions of the global economy, and changes in technological and institutional capabilities within China. This will require not only a thick network of ties for international cooperation, but it again points to the need to understand what a proper role of government should be. Meeting this latter challenge may be the most difficult part of developing an innovation strategy for the new century.

One of the more interesting lessons from Chinese experience is the unfolding of a range of innovative activities which were not fully anticipated by the innovation strategy. To understand these, we should recall that China's reform policies have created opportunities for the growth of civil society where none existed before. But, this is a civil society which maintains complex dependent relationships with the state. Chinese society has come to have significant zones of autonomy for economic activities, but the autonomy involved is not unlimited - both as a result of the exercise of state power *and* as a reflection of the preferences and choices of those who enjoy the opportunities presented by autonomy. So, too, with the development of activities relating to technological innovation. Entrepreneurship in high-technology industries - most often associated with the "new technology enterprises" which began to develop in the 1980s - gives China opportunities for innovative capabilities which can't be programmed or planned in a national innovation strategy. At the same time, limitations on successful entrepreneurship - deriving from imperfections in the reform program, the relative weakness of Chinese firms, and the challenges from the international environment noted earlier - point to a continuing need for an active government role in building national innovative capacity.

Thus, the inherited technical assets of the state remain important resources for those engaged in technological and institutional innovations in the zones of autonomy which now exist. Nowhere is this better exemplified than in the dynamism seen in the Zhongguancun area of Beijing where many of the more successful firms have relied - or continue to rely - on technologies developed by state entities.[42] But as the interesting discussion of Zhongguancun in the chapter by Wang and Tong points out, the possibilities of creating China's "Silicon Valley" in Zhongguancun offered by the entrepreneurial zeal and high concentration of intellectual prowess found there, are far from being realized.[43] Serious constraints on the creation of a climate of innovation persist which have eluded the innovation strategy. These include continuing uncertainty over property rights arrangements and a serious lack of social trust, both of which, work against the development of an effective, high technology, networked economy. In addition, finding and developing high-level human resources is a constant problem for small entrepreneurial firms who are reluctant to incur the costs of training when employee turnover is so rapid, especially in the face of a rising demand for Chinese professional manpower coming MNCs - whose presence will only increase with WTO membership (Wang and Tong).

In the face of these difficulties, the entrepreneurs of Zhongguancun continue to look to the state for protection and, thus, would seem to compromise the development of a highly competitive, risk-taking culture which China's leaders, and members of the business and technical communities, otherwise recognize as essential to realizing the nation's innovation aspirations. A range of constructive, market-conforming government responses to these problems, which would not smoother the new entrepreneurship, are clearly imaginable. However, thoughtful observers might question whether they will be forthcoming in light of the widespread corruption, tolerance for

[42] Lu, 2000; Lu, 2001.
[43] See, also, Cao, 2001.

fraud, limitations on dissent, and subordination of entrepreneurial actions to state interests which characterize today's political economy. All seemingly inconsistent with the creation of a culture of innovation, and all seeming to require some sort of more radical political reform to remedy, the existence of these problems would seem to constitute a major limitation on the effectiveness of the innovation strategy.

Thus, as China begins to confront the more subtle and diffuse policy challenges required to move its innovation strategy beyond an "S&T policy" orientation toward one focused more on creating cultures of innovation and a more innovative society, new approaches to defining the role of the state will be hard to avoid. Moving to this next stage will require attention to both the positive policy roles government should play *and* the limits on government powers. It is unlikely that workable definitions will be found without entertaining a broader set of questions concerning how the behavior of the state affects the core values associated with successful innovation - those relating to creativity, efficient communications, social cooperation, and risk taking and entrepreneurial zeal. These are questions which are central to the ways rights and responsibilities are approached in state-society relations, and entertaining them will not be easy. One senses, though, that without doing so, the innovation strategy on which so much rests will be frustrated in its execution.

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