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Members of the Commission. Thank you for the opportunity to present some of my views on this important topic. It is a pleasure to be here with you again.

The subject of innovation in China has attracted worldwide attention in recent years, and there has been much disagreement about China's innovational capabilities and achievements. I think we are gradually coming to a better understanding of these issues as seen for instance in a series of useful reports on the subject, including the report submitted to the Commission last year by CENTRA Technology.[1] These various studies are giving us a better sense of the assets and liabilities China brings to the challenges of innovation. Let me consider some of these briefly here.

China is clearly demonstrating a capacity for significant research and engineering achievements as seen, for instance, in the growth of scientific papers published in international journal and notable engineering accomplishments in such fields as space, ocean engineering, supercomputing, materials technology, and hydraulic engineering. At the same time many Chinese associated with innovation policy, and a number of foreign observers, recognize significant problems with China's national innovation system.[2] To begin to understand these somewhat conflicting phenomena, it is helpful to look at some of the more important aspects of China's innovation ecosystem.

At the outset, we should recall that there are powerful drivers of innovation at work in China. In addition to the serious commitment to national action plans for innovation from the

[1] *China's Program for Science and Technology Modernization: Implications for American Competitiveness.* See also, The World Bank. *China 2030: Building a Modern, Harmonious, and Creative High-Income Society* ("Supporting Report 2") (2012); The Center for American Progress. *Rising to the Challenge* (2011); and the recent brief report produced by McKinsey's Shanghai office, "How China Is Innovating." (2012)

[2] Cf., OECD. *OECD Reviews of Innovation Policy: China*. 2008.

political elite, these would include an enormous consumer market, important trends in urbanization and infrastructure development (both engendering large-scale public investments), major resource and environmental challenges, and an enormous reservoir of bottom-up entrepreneurial energy.

Located between these drivers and the successful and not so successful outcomes of research and innovation activities is a set of institutions of considerable diversity. These include, first, a sector of academic research led by the Chinese Academy of Sciences (CAS) and China's leading universities. A second sector of industrial research and innovation involving Chinese companies is characterized not only by differences among various type of industry, but also by notable regional, ownership, and size differences. Thus, it is difficult to generalize about the nature of innovation in a sector that includes large state-owned enterprises and private firms, which displays both the effects of powerful central planning and the play of entrepreneurial energy, which includes firms that are deeply involved with global production networks, and those that are more purely domestic in orientation, and firms with highly cosmopolitan professional staffs, and those whose experiences are largely limited to economic activities in China. The institutional mix is further complicated by the existence of a large defense sector which is increasingly committed to the development of dual use technologies and civil-military integration, by other government research institutes supporting the supply of public goods (agriculture, health, environment, etc.), and finally by the presence of multinational corporations, some 1300 of whom now have R&D centers in China of one sort or another.

In short, it is difficult to talk about a simple undifferentiated national innovation system in the face of such diversity, especially when we consider the growing role of local governments in supporting research and innovation. In addition, at both national and local levels, we see interesting initiatives at institutional innovation in support of new public-private partnerships and new innovation "platforms" to facilitate the development of networks of cooperation among industry, universities, and government research institutes in support of the policy objective of *xietong chuangxin* ("cooperative," or "collaborative," innovation).

As you know, China is providing resources for this system of institutions with increasingly generous funding, attention to the cultivation and recruitment of technical talent, and the provision of a variety of technical support services, including those focused on the creation and management of intellectual property.

China has also been creative, and largely successful, in exploiting globalization to promote its science and technology. It has tapped into the diaspora of Chinese scientists and engineers in profitable ways, it has exploited opportunities for advanced overseas training, and it has developed a robust approach to international scientific cooperation. With its mix of domestic support policies and international outreach, it is becoming a magnet for MNC R&D investments, for foreign professionals seeking research opportunities in China, for Chinese scientists and engineers who once were lost in the brain drain, and for foreign governments seeking to build scientific and technological cooperation with China.

In spite of these many positive developments, China's innovation system also faces a number of problems. These include, first, widely expressed concerns that Chinese research and innovation are characterized by a serious lack of originality and creativity - what might be called the "Steve Jobs problem."[3] In addition to the creativity issue, and probably related to it, are the issues of serious scientific misconduct and widespread problems of commercial integrity. To these could be added problems with existing institutional arrangements - R&D spending outpacing good management, problems of stove piping and national coordination, long-standing problems of research and innovation in industrial enterprises (weak in-house R&D, weak linkages between research and economy) which have stubbornly defied easy solution, and finally, an unresolved tension between techno-nationalist and techno-globalist impulses (or, the "what does 'indigenous innovation' mean in an age of globalization?" question).

Explanations for these problems, and why China's aspirations for innovation are sometimes frustrated, involve economic, cultural institutional, and political factors. In economic terms, we can point to some serious disincentives (abundant labor, narrow profit margins, availability for foreign technology, etc.) which discourage innovation. Culturally, the education system is weak on encouraging "outside the box" thinking, and continues to promote excessive respect for hierachical authority. Institutionally, the weak rule of law generally, and weak intellectual property rights protection more specifically, combined with inappropriate venture financing, frustrates innovative activities. Finally, in political terms, the strong belief in state directed, top-down innovation biases the innovation system away from what could be more productive bottom-up approaches, and an information

[3] On the occasion of Jobs' death, many Chinese were asking why China has not and, perhaps, could not produce a Steve Jobs. In response, the city of Ningbo, reportedly, initiated a new plan to produce Steve Jobs!

culture which privileges political control of information as a default assumption, also imposes constraints on the innovation system. Certainly, by Western assumptions about innovation, China seems to be trying to "square the circle" by simultaneously calling for the creation of an "innovative society" while also seeking to enforce the tenets of a "harmonious society" by authoritarian means.

In the remainder of the submission, let me try to address some of the more specific questions you have raised.

1. How do such national programs as the 863 and 973, the key laboratory program, and the Medium and Long Term Development Plan (MLP) affect innovation in China?

First, it is important to note that these numbered programs (863, 973) of the Ministry of Science and Technology (MOST), while important, represent a relatively limited percentage of national expenditures on R&D. The share of the R&D budget directly controlled by MOST is estimated to be less than 20%, and this includes more than the numbered programs. That said, these programs have undoubtedly helped Chinese scientific and technological development. The question, though, has been whether they have been cost-effective. 863, for instance, was originally conceived as a program for catching up with the international frontier in high-technology. While it certainly has contributed to high-tech development in a variety of fields, the international frontier itself has not remained stationary. It is not clear whether 863 has led to a reduction in the gap between the two, or a widening.

Another critical question about these programs has been, and continues to be, whether they are administered properly. Questions have been raised about the quality and suitability of peer review in decision-making about program priorities and project funding, and about the susceptibility of the programs to corruption. In the views of at least some scientists, the programs have not really fostered original research and innovation, and the reason lies with the administrative arrangements and institutional design.

With the initiation of the MLP, China launched a multifaceted strategy of national mobilization in support of science and innovation involving major research initiatives and a number of supporting measures intended to more fully integrate national R&D projects and industrial policies. Again, there is little doubt that the set of policies making up the MLP are advancing Chinese capabilities in research

and innovation, but the question of cost effectiveness is again prominent. A great deal of money for research and innovation is now "sloshing" around China, but there seems to be a growing concern that funding increases have outpaced sound administration.

It is fair to say, I believe, that the history of China over the past three decades indicates that Chinese leaders take the country's problems seriously, learn from mistakes, and in an iterative fashion, attempt to correct institutional failures. There is again, today, active discussions about future reform of the S&T system which recognize that the next steps in reform will not be easy. But, there is also a recognition that the future performance of the innovation system is contingent on them.

Finally, it is important to recognize that one of the more important aspects of the MLP is its emphasis on research and innovation in industrial enterprises in order to make the enterprise sector the core of the innovation system. This has led to a redirection of policies in favor of enterprises as seen, for instance, in a greater share of 863 money going to industry and the establishment of new national laboratories in companies.

2. Is China's model of highly centralized R&D planning effective? Does China's leadership appear to be adhering to this model or moving away from it?

The effectiveness of centralized R&D planning is, to some extent, a function of the nature of the work at hand. China's success in major engineering projects, such as those noted above, is due in part to a centralized scheme to mobilize resources to attack high priority technological missions.[4] In this sense, China is not unique;

[4] It is notable, in this context, that in a recent ranking of the top 10 S&T news stories for 2011, chosen by academicians of the Chinese Academies of Science and Engineering for the *Science and Technology Daily*, the majority involved projects that would likely benefit from centralized planning and direction. The top 10 included:

1) The successful test flight of the J-20stealth fighter;
2) The first time a national science and technology award was revoked because of fraud;
3) The launch of three more navigation satellites to support the Compass navigation system;
4) The discovery that body cells can be directly induced to become liver cells;
5) China's first fast neutron reactor becoming part of the power grid;
6) A Chinese made manned submersible reaching a record depth of 5000 m;

such an approach is found in many other countries, including the United States. However, the appeal of this centralized planning model is more deeply ingrained in Chinese decision-makers than is the case in other countries in part because of the success of the strategic weapons programs of the past, and the belief that former major planning efforts have effectively advanced Chinese scientific and technological capabilities. In addition, this approach is seen as suitable for a developing country as it seeks to "catch-up" to international frontiers, and, again, one can find evidence of its effectiveness in other countries.

This model is less appropriate for other projects, though, and for moving beyond "catch up." The emphasis upon centrally directed programs can work against curiosity driven research and bottom-up entrepreneurial innovation. For instance, there have been a number of allegations that Chinese entrepreneurial startups have been disadvantaged by China's policy profile which, until recently, tended to be insensitive to innovation initiatives that were not part of the plan and the policy benefits therein.

We should recognize, though, that the Chinese innovation system should not be characterized, solely, as being driven by central research and industrial planning. As noted in the discussion of institutional variety, above, the innovation system is too complex and variegated to be described in simple terms. In addition, in terms of research programs, curiosity and investigator driven projects are eligible, although these usually have to fit into some sort of predetermined program definition. Those program definitions are more demanding at the Ministry of Science and Technology (MOST) than they would be at the Chinese National Science Foundation (NSFC), although even at the latter, the programs for larger grants specify program objectives into which projects must be fitted.

It is unlikely that the deep-seated preferences for a centrally planned system will be abandoned any time soon in large part because, in some circumstances, they have worked well. However as China attempts to move beyond catch-up, as it seeks to better utilize the pools of technical entrepreneurial talent that exist, and as it

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7) The "Chang-e II" moon probe satellite reaching the L2 Lagrange point, allowing Chinese scientists to probe targets in deeper space;
8) Tu Youyou winning the Lasker Award for work on artemisinin;
9) The Shenzhou-8 capsule docking successfully with Tiangong-I; and
10) The success of the University of Science and Technology of China in working out an eight-photon entangled state.

interacts more fully with the global innovation system, the use of the centralized R&D planning model is likely to be more circumscribed.

It is useful, in this context, to recall that the distribution of activities in China's national R&D profile reflects the overwhelming preference for technological development (over 80% of national R&D expenditures), as opposed to basic and applied research. The administrative arrangements for development work will differ markedly from the exploratory activities of basic and some applied research. As China seeks to "leapfrog" into leading positions in new science-based industry, it will have to give greater attention to exploratory research and to new approaches to R&D management and administration.

3. What are the prospects for more market-driven innovation? Is there any real innovation going on in China's private sector?

As the discussion above suggests, we can expect market-driven innovation to become much more important in the coming years. But we should also recognize that market-driven innovation is already well-established and widespread. As Kevin Wale, president of GM China, noted recently, "What China does better than any place else in the world is to innovate by commercialization, as opposed to constant research and perfecting the theory, like the West. When the Chinese get an idea, they test it in the marketplace. They're happy to do three or four rounds of commercialization to get an idea right, whereas in the West, companies spend the same amount of time on research, testing, and validation before trying to take products to the market."[5] Wale goes on to note, "in our business in China, if we don't innovate through commercialization, we're going to lag behind our competitors." Market forces drive the "shanzhai"[6] culture characteristic of South China, and lie behind diverse innovations in consumer products more generally, as well as in business model innovation and innovations in supply chain management, areas where China is also often seen as a trend setter.

The play of market forces also helps explain why there is considerable innovative activity in the private sector, in spite of policy preferences being biased against

[5] Kevin Wale. "Automotive Innovation in China: The View from General Motors." In, McKinsey report. "How China Is Innovating."

[6] "Shanzhai"has come to describe the practice of copying or imitating foreign technology (often without regard to IPR), and then adding distinctive functionality to a device, at lower cost, that responds to Chinese market preferences.

private companies. There is a growing recognition that the policy preferences enjoyed by state owned enterprises protect them from market forces and actually work against the cultivation of cultures of innovation in those enterprises.

Various indicators support the view that the private sector has become active in innovation. For instance, according to 2005 figures, of the103 companies which were designated by MOST as "experimental innovative enterprises" that year, 77 were private. Of the 10 most successful Chinese companies in securing invention patents in 2009, eight were private. Other research shows that private companies take their R&D missions more seriously than SOEs in terms of the intensity of expenditures and the recruitment of qualified technical personnel. In order to capture more of the entrepreneurial energy found in the private sector, it appears as if the national government and local governments are doing more to support the expansion of private sector innovation oriented firms.