Leapfrogging Development through Nanotechnology Investment: Chinese and Indian Science and Technology Policy Strategies

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Nanotechnology has been dubbed the next technological "revolution" by some. The attention that it has attracted by developed and developing country governments is staggering. With payoffs not expected for a minimum of 10 years, investment has continued to grow, globally as countries attempt to claim a stake in what is predicted to be a $2.6 trillion industry by 2014 (Holman et al 2006). This paper is part of a larger project that will attempt to address some of the central differences between China and India with respect to how the two countries are approaching high-technology development. This paper is based off of research related to China's nanotechnology policy environment conducted over the past two years at the Center for Nanotechnology in Society, a National Science Foundation supported center at the University of California, Santa Barbara. Following my participation in the Young Scholars Program in the summer of 2008, preliminary research was conducted relating to India's nanotechnology policy environment. Both countries are attempting to pursue high-technology development as a means of fostering economic growth through leapfrog development, a phrase that features prominently in China's policy discourse, primarily by the Ministry of Science and Technology (MOST). The concept is intended to describe the country's efforts "to aim at the forefront of world technology development, intensify innovation efforts and realize strategic transitions from pacing front-runners to focusing on 'leap-frog' development in key high-tech fields in which China enjoys relative advantages" (MOST n/d).

The concept of technological leapfrogging was coined in 1985 by Luc Soete with specific reference to the international diffusion of technology and the industrial development of economic growth associated with the microelectronics industry. Soete highlights the significant advantages that can be felt by "late industrializes" in terms of catching up to the global technological leaders, citing Japan as the most apt example (at the time) of successful leapfrogging. Most recently, technological leapfrogging has been linked to countries like China and India, with direct reference to "leapfrog development" in official policy documents. Both China and India have deliberately focused their efforts on high technology growth as a means of fueling economic development, rather than relying only on streams of foreign aid or the more traditional approach to development in "stages of economic growth" typically advocated for developing economies (Rostow 1960) as they seek to modernize through heavy investment in industrialization. Instead, China (and India as well) is moving toward high-technology development while simultaneously continuing to exploit its comparative advantage in labor-intensive industries (Friedman, 2006). If successful, through leapfrog development, both countries (and by implication other developing countries) could potentially prompt considerable shifts in the global economy not only in terms of technology transfer, economic activity and income, but also by lessening the environmental degradation typically associated with industrial development through the adoption of more efficient and modern technologies (Perkins and Neumayer 2005). Newly industrializing economies in general, but India and China in particular, have confronted a good deal of criticism over their highly polluting industrial development (Adams 2001, Porter and Brown 1996, Ho 2005). Because of the broad set of challenges faced by these rapidly-growing economies such as (but not limited to) poverty alleviation, food security, protection of national resources, Ho poses the critical question: "How can the State affect environmental reform in the industrial sector without inhibiting economic growth?" (2005:210).

China and more recently India have both focused their science, technology, and innovation policies around funding for nanotechnology R&D amongst other high-tech approaches. In both countries, however, there are perceived tensions between stated policy goals which promote economic and industrial development on the one hand, and socially and environmentally sustainable development on the other. Particularly in the case of Chinese policy documents, there is frequent reference to building a more "harmonious society" (hé xié shè huì/和谐社会) as a means of counterbalancing such tensions (Appelbaum and Parker 2008).

Both countries have been experiencing unprecedented growth (China at a rate of more than 10 percent annually for two decades; NBSC 2005 and India at a rate between 8 percent and 10 percent annually for the last decade; CIA 2008). In addition to the economic advantages of rapid growth, the increasing strength of educational, research, and commercial infrastructure is allowing more overseas Chinese (and arguably, Indian's) to return home with increased job security and expectations of higher standards of living (Wagner 2006, Zhou and Leydesdorff 2005). Overseas Chinese constitute an important source of the dynamism of Chinese nanotechnology, and are of central importance when examining the impact of international collaboration to achieving the country's political and economic goals to leapfrog development and become a leading technology exporter.

Along with such rapid economic development in China, government planners are looking to mitigate further environmental destruction - and the social unrest that has occurred as the result of toxic water spills, flooding, etc. through the promotion of integrated resource planning and technology-promoting policies which aim to not only generate more domestic production of pollution control/energy efficient products to revive China's environment, but in turn promote technological leadership in the exportation of new green technologies. Policy makers believe that in creating clean-technology oriented markets, the promotion of a truly harmonious development cycle may be possible (Lü, Totten and Chou 2006).

The selection of nanotechnology as one of four science megaprojects (Development and Reproductive biology, Nanotechnology, Protein Science, and Quantum Research) for technology development fits the criteria for leapfrog development well. Chinese political leadership has lent its support together with a significant push from the scientific leadership, both inside and outside China. The decision to include nanotechnology as one of the country's four science megaprojects was influenced in part because of the perceived promise that nanotechnology holds in making advances not only in basic science but also in applied science and subsequent to that, with economic development. The fact that globally, countries such as the US had formulated national nanotechnology initiatives ultimately made it easier for Chinese, Indian, and other developing countries scientists and engineers to make their case to scientific and political leadership that nanotechnology was worth pursuing, despite the relatively long time horizon to product development. In the case of China, the connection of Chinese scientists to the international nanotechnology community, and especially to Chinese scientists abroad, has helped the country move toward the frontier of international nanotechnology research.

In recent months India has made its efforts to develop nanotechnologies more substantial. India's federal government has directed $250 million toward the national initiative in support of nano technological research. Sabeer Bhatia, co-founder of Hotmail plans to build a multibillion dollar "nanocity" in Chandigarh, northern India, envisioned as the "Silicon Valley" of India. In the United States, Indian-Americans have already begun to show their support for a national nanotechnology initiative in India through a program dubbed the "Indus Nanotechnology Association" which hopes to provide a common platform for researchers, entrepreneurs, technologists and investors of Indian origin seeking to leverage the emerging nanotechnology industry (Krishnidas 2007). Thus, the role of Indian's living abroad appears to be as dynamic as that of the Overseas Chinese in terms of the support for and impact of R&D of nanotechnology.

Following the precedent set by the United States, Germany, China, and others, the Government of India has begun to realize the potentially significant economic impact of nanotechnology through an investment of Rupees1000 crore (roughly $230 million) funded through the Department of Science and Technology (DST) and Nano Science and Technology Initiative (NSTI) to provide support for the strengthening of the country's scientific and technological infrastructure to academic institutions, R&D institutes & national laboratories

India feels particular pressure to invest in nanotechnology R&D at an early stage because of the perception of an opportunity "lost" in failing to play a major research role in the superconductor revolution in the 1950s (Rao 2008). Further, there is additional and significant pressure from inside India to become a major player in the advancement of science and technology globally "instead of just being provider of nurses and IT workers, the country should emerge as a provider of knowledge" (Rao 2008). Aside from technological innovation, the country's policy leaders are calling for policy innovations in research directives so as to ensure that scientific and technological breakthroughs will benefit the poor and other marginalized groups in the country (Mashelkar 2008).

Thus, one aspect of India's nanotechnology policy strategy that is unique to India (as compared to China) is the focus on the development of nanotechnologies with the specific intent of harnessing emerging technologies to meet the needs of India (and by implication, of the developing world). One of the preeminent nanotechnology scholars in

India explains that in developing countries, "where pre-industrialized and post-modern forms of technologies coexist with newly emerging technologies, nano-engineered commodities and services can be designed for the needs of people belonging to pre-industrialized, post-modern or knowledge societies, since no preclusions apply" (Burgi and Pradeep 2006:648). Similar to China, India is depending on its strong numbers in terms of human capital/human resources capacity for becoming a world leader in nanoscience and nanotechnology (Krishnadas 2007). To this end, in India, there is general consensus amongst policy planners that harnessing "human capital and their brainpower in the medium and long-term, will reshape the imbalance between the North and South" (Burgi and Pradeep 2006).

Under the current (11th) five year plan, the planning commission has called for the funding of nanotechnology institutes and centers of excellence with an eye toward developing products and technologies, spreading interest in nanotechnology by establishing laboratories in universities (in the hopes of developing the manpower needed to become a global leader). Other efforts include a major program using nanotechnology to improve performance of photovoltaics. While India has chosen not to directly hedge bets on any one particular type of nanotechnology, planners have indicated general areas where they expect breakthroughs might occur such as nano-sensors (again, it is important to emphasize the focus on social benefit; such sensors will be essential for detecting environmental contaminants). Similarly, the planning commission has recommended ways to harness nanotechnology, biotechnology and bioinformatics to transform Indian agriculture, including creating a national institute of nanotechnology in agriculture (Sreelata 2008).

The role played by the Indian government in designing the national nanotechnology initiative has only recently picked up pace, and many of the country's leading science and technology experts have expressed disappointment in the relatively small amount of funding dedicated to nanotechnology R&D (Anon, 2008). As mentioned above, The Department of Science and Technology (DST) allocated approximately $230 million in the present five-year plan under the national "Nanomaterials Science and Technology Initiative." Under the plan, several academic institutions in India have been awarded funding to increase their capacity toward building the necessary facilities to compete at a global level and become research centers of excellence, with highly educated and trained workforce, state-of-the-art research infrastructure and foster ties to both Indian and foreign industry and business partners. Funding for nanotechnology R&D in India is intentionally very broad at the present and there is a sense that "if you were to centrally try to clearly define strategic areas in nano there wouldn't be enough applicants... we first need to build up a critical mass" (Sastry 2008).

Interestingly, while China's efforts on the one hand, are squarely focused on developing key technology areas that the country's technocratic leadership have identified as holding strategic importance, those in India, on the other hand, have so far preferred to stay clear from the strategy of "picking winners" and have instead funded infrastructure for the development and enhancement of nanotechnology as a whole (although there is clearly a concerted effort amongst the technologists that the need should be on developing sustainable nanotechnologies *for India*. Although many newly industrializing countries (in addition to China and India) have nanotechnology featured prominently in their national research initiatives, according to the Woodrow Wilson Center “there is still a danger – if market forces are the only dynamic – that small minorities of people in wealthy nations will benefit from nanotechnology breakthroughs in the health sector, while large majorities, mainly in the developing world, will not” (Maynard 2007). Nonetheless, there is a burgeoning literature exploring potential promises of nanotechnology for alleviating problems of health, equity, and poverty (Michelson 2008). Thus, the role played by these two countries in developing nanotechnology (and other technological) breakthroughs is of particular importance as these two countries continue on such rapid economic development trajectories so as to mitigate the tensions of industrialization and growth as equitably as possible.

Through participation in the “China-India-US Workshop on Science, Technology and Innovation Policy” I was able to do preliminary research that will add a second case study to my dissertation, entitled: "Innovation and International Collaboration: Development and Environmental Sustainability through High Tech Industry Growth in Emerging Economies." The dissertation will attempt to highlight the ways that China and India are using nanotechnology (as one example) to address problems associated with their rapid industrialization and growth such as water, air, and soil pollution. The opportunity afforded to me by participating in the workshop in Bangalore and the subsequent interviews I conducted in Chennai, Mumbai, and Pune were enormously helpful in terms of clarifying and solidifying the scope of my dissertation. The opportunity enabled me to lay the groundwork for the second case study and I have subsequently been awarded further support to return to India as a direct result of the research conducted in the summer of 2008.

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