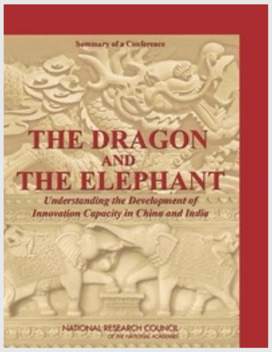

The Dragon and the Elephant: Understanding the Development of Innovation Capacity in China and India: Summary of a Conference

DETAILS

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THE DRAGON AND THE ELEPHANT

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Summary of a Conference

Stephen Merrill, David Taylor, and Robert Poole, Rapporteurs

COMMITTEE ON THE COMPETITIVENESS AND WORKFORCE NEEDS OF U.S. INDUSTRY

BOARD ON SCIENCE, TECHNOLOGY, AND ECONOMIC POLICY

POLICY AND GLOBAL AFFAIRS

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For the National Research Council (NRC), this project was overseen by the Board on Science, Technology, and Economic Policy (STEP), a standing board of the National Research Council established by The National Academies of Sciences and Engineering and the Institute of Medicine in 1991. The mandate of the STEP Board is to integrate understanding of scientific, technological, and economic elements in the formulation of national policies to promote the economic well-being of the United States. STEP bridges the disciplines of business management, engineering, economics, and the social sciences to bring diverse expertise to bear on important public policy questions. The members of the STEP Board and the NRC staff are listed below.

Preface

Until recently, competition for the United States in high technology goods and services has come from Japan and the countries of Western Europe, but this situation is rapidly changing. There has been remarkable growth in innovative capabilities in a number of countries that 30 years ago were classified as developing economies. Taiwan and South Korea, followed by China and India, are the leading examples of this phenomenon.

These developments are part of a new phase in the globalization of the innovation process. Since at least the 1960s large multinational companies from industrialized countries have been moving much of their manufacturing and some of their research and development (R&D) activities offshore, but most of the latter was restricted to development activities intended to modify existing products for foreign markets. Beginning in the 1980s, however, a new pattern began to emerge. The R&D activities that were moved offshore began to include more "upstream" activities, including original research, and the companies involved started to collaborate more extensively with universities, public laboratories, and firms of the host countries. With the disintegration of self-contained, integrated innovation chains within large companies, smaller, younger firms began to play a larger role in this R&D offshoring; and the companies involved came to include many more non-manufacturing firms than had previously been the case. Finally, the destinations of the offshored R&D activities shifted, with more going to industrializing economies, especially those in East Asia such as Taiwan and South Korea, and also to the lower-income, very large developing economies of India, China, and Brazil. In short, after an era that saw the dispersion of manufacturing activity in search of low-cost location for production, the world is entering an era in which innovation itself is far more widely distributed than previously.

For the past three years the Academies' STEP program, with funding from the U.S. Department of Education, U.S. Department of Commerce, and the Alfred P. Sloan Foundation, has been studying the globalization of innovation with a series of activities. A pair of workshops in 2006 and 2007 and commissioned papers led to the publication of *Innovation in Global Industries: U.S. Firms Competing in a New World* (NRC, 2008). This collection, edited by Berkeley Professor David Mowery and Georgetown Professor Jeffrey Macher, examines changes in innovation patterns in ten service as well as manufacturing industries – personal computing, software, semiconductors, flat panel displays, lighting, pharmaceuticals, biotechnology, logistics, venture capital, and financial services.

Because of the growing importance of China and India to this process and their potential to profoundly affect the distribution of innovative activity and investment around the world, an ad hoc committee under the STEP program decided to organize a symposium focusing specifically on the role that those two countries are beginning and likely to play in the globalization of innovation. That conference, "The Dragon and the Elephant: Understanding the Development of Innovation Capacity in China and India," was held in Washington, D.C., on September 24-25, 2007, and drew participants from both countries, the Organization for Economic Cooperation and Development (OECD), and the World Bank as well as the United States. The meeting was organized with the assistance of the Levin Graduate Institute of the State University of New York, Woodrow Wilson International Center for Scholars, Urban Institute, and Athena Alliance.

In his opening remarks as chairman of the conference, David Morgenthaler observed that innovation can mean several different things. It can refer, for example, to producing more of what already exists and adapting existing capabilities, such as cell phone technology, to the specific needs and resources of a particular customer base, such as the populations of China or India. It can refer to institutional changes such as those needed to take advantage of technical advances or scientific discovery. And it can refer to political system changes, market improvements, and new business models.

China and India face all three challenges—development of new science-based technological advances to satisfy growing middle- and upper-class populations, technology adaption and application to alleviate great poverty, and institutional change to sustain economic progress. Because of their great size, how well India and China succeed in this endeavor will have a great bearing not only on their own populations' welfare but also on global economic welfare. It is this grand experiment or series of experiments that the symposium participants endeavored to illuminate and explore.

The symposium was designed to offer a snapshot of where these two countries are now as they strive to improve their capacity to innovate and to explore what can be expected from them in the near future. Although many people who are unfamiliar with the situation see China and India as having very similar economic trajectories, the economies of the two countries are actually very different. Each has its own strengths as well as weaknesses and challenges to overcome in order to become a globally important center of innovation in a range of technologies and industrial sectors.

This document is a summary report of the presentations and discussions that took place at the conference. The planning committee's role was limited to planning the conference. This summary report was prepared by consultants and the study director. The views expressed in this summary are those of the speakers and discussants and are not the consensus views of conference participants, the planning committee, the Board on Science, Technology, and Economic Policy, or the National Academies.

The organization of the document follows the organization of the symposium, whose agenda can be found in Appendix A. Chapter 1 offers an overview of the current recent performance of the Chinese and Indian economies and their roles in the global economy, while Chapter 2 describes various ways in which United States interests are affected. This is followed by a series of chapters examining the factors contributing to and in some cases inhibiting the development of world class innovation capacity. Chapter 3 discusses human capital in the two countries and summarizes the keynote speech of Satyanarayan Gangaram Pitroda, Chairman of the Indian National Knowledge Commission, whose remarks focused primarily on human capital development in India. Chapter 4 covers capital markets and investments; Chapter 5 looks at research and commercialization infrastructures; and Chapter 6 examines the legal environments in the two countries as they affect the development of innovation capacity. Chapter 7 offers a look at the two countries from the perspective of multinational corporations. Chapter 8 contains summaries of four separate breakout sessions that compared developments in four key industrial sectors in the two countries—information technology, transport equipment (automobiles and aircraft), pharmaceuticals and biotechnology, and energy. Finally, Chapter 9 summarizes some of the conference speakers' and participants' final observations.

An effort was made to select and guide presenters to enable comparisons between China and India along the same dimensions, but it was not always possible to adhere to this standard. For example, although the evolution of intellectual property policy in both countries has attracted much attention and was addressed in the conference, it was difficult to find experts in Indian competition and technical standards policy.

During the conference there was also a poster session in which nine young scholars presented recent research on innovation-related developments in one or both countries. The list of participants in this session and their research topics can be found in Appendix B.

The National Research Council (NRC) and the Board on Science, Technology, and Economic Policy (STEP) are grateful to principals of the four co-organizers of the conference—Denis Simon of the Levin Graduate Institute of the State University of New York, Kent Hughes of the Woodrow Wilson International Center for Scholars, Hal Salzman of the Urban Institute, and Kenan Jarboe of the Athena Alliance. In addition to the Alfred P. Sloan Foundation, U.S. Department of Education, and U.S. Department of Commerce the following provided financial or in-kind support without which the conference would not have been possible: The Levin Graduate Institute, Indo-U.S. Science and Technology Forum, National Science Foundation, Office of Naval Research, Booz Allen Hamilton, Eli Lilly, Inc., Hewlett Packard, Inc., and Microsoft, Inc. Most indispensable to the meeting's success was the participation of public officials, private sector leaders, academic experts, and others knowledgeable about economic developments in China and India, many of whom traveled very long distances to attend.

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Academies' Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for quality and objectivity. The review comments and draft manuscript remain confidential to protect the integrity of the process.

We wish to thank the following individuals for their review of this report: Sean Dougherty, Organisation for Economic Co-operation and Development-Paris; Vinod Goel, The World Bank; Jeffrey Macher, Georgetown University; Thomas Ratchford, George Mason University; and Harold Salzman, Rutgers University.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the content of the report, nor did they see the final draft before its release. Responsibility for the final content of this report rests entirely with the authors and the institution.

Stephen A. Merrill, Study Director

Contents

Summary

The return of the once-dormant economies of China and India to dynamism and growth is one of the most remarkable stories in recent history. The two countries are home to nearly 40 percent of the world's population, but until recently neither had played an influential role in the contemporary global economy. Just a few decades ago, for example, Americans associated the words "Made in China" with simple, cheaply made manufactured goods of questionable quality and identified "Made in India" with little but crafts and colorful textiles.

In the past two decades, China and India have liberalized internal economic policy, treatment of foreign investment, and trade, and have experienced economic growth at sustained high rates. China's gross domestic product has been growing at an annual rate near 10 percent for more than two decades, and now ranks as having the fourth largest output in the world, according to the Organisation for Economic Co-operation and Development (OECD).[1] China has become a major exporter of manufactured goods, including high-technology items, and a destination of first or second choice for foreign investment. The Chinese population has seen a steady increase in average income, and there has been a sharp drop in poverty rates.

India's rise has been almost as impressive. For the past 20 years its gross domestic product (GDP) has increased at an average annual rate of more than 6 percent; more recently (2003-2007) the rate was higher, 8.6 percent per year (Panagariya, 2007). In the three years from 2003 to 2006 India doubled the value of goods it exported to the rest of the world, while the export of services grew even faster, more than doubling in the two years from 2004 to 2006. Much of the export growth has come in high-technology industries, particularly software.[2]

From the point of view of the United States, however, the most important development in the Chinese and Indian economies in the long term may be the strides they are making in developing their own domestic innovation capacities. After a long period of under-investment, both countries have committed to growing their science and education systems to bolster research and further economic expansion. Already there are demonstrable albeit different levels of results in terms of R&D spending growth, numbers of science and engineering graduates at all levels, shares of scientific publications, numbers of domestic and foreign patent filings, and other measures.

Some observers of the recent growth have said that both countries are surging in their efforts to spur innovation; others have emphasized the potential of one country over the other; and still others have suggested that both China and India have a long way to go before achieving innovation-driven growth. With such a range of views, The National Academies' Science, Technology, and Economic Policy

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[1] In general, there are two ways of comparing national economies. The market exchange rate (MER) method reports the nominal value of a statistic (e.g. GDP) as calculated at the market official exchange rate; the purchasing power parity (PPP) method accounts for differences in the cost of living between countries. By the MER method, China has the fourth largest GDP; by the PPP method it has the second largest economy.

[2] The global economic crisis was only beginning at the time of the conference, but developments since suggest that China and India have weathered the crisis better than many other countries. In October 2009 the International Monetary Fund projected that the U.S. economy would contract by 2.7% in 2009 while that of China and India would grow by 8.5% and 5.4% respectively (all projections refer to real GDP changes).

(STEP) Board set out to describe developments in both countries, in relation to each other and the rest of the world, by organizing a conference in Washington, D.C., to discuss the recent changes at the macroeconomic level and in selected industries and their causes and implications. The meeting drew academic experts, private sector leaders, and public officials from both countries and international organizations and attracted an audience in excess of 350 people.

Titled, "The Dragon and the Elephant: Understanding the Development of Innovation Capacity in China and India," the conference yielded observations about policy priorities in both countries as well as some observations about how the U.S. might respond. Meeting on the 50^{th} anniversary of the launch of Sputnik by the U.S.S.R, speakers noted that just as that event spurred a renewed U.S. commitment to science and engineering education and to research, the economic challenges posed by the rise of China and India could stimulate a similar renewal.

China and India share some characteristics, such as enormous populations and domestic markets, deeply-rooted cultures, recent histories of liberalizing formerly collective economies, and extensive diasporas of highly trained people. But there are significant differences in many areas, including demographics (India has a younger population), education systems, capital markets, infrastructure needs, and levels of GDP and research investment. Perhaps the most salient difference is in political regimes—between democratic India and authoritarian China. The relationships among regime type, economic liberalization, growth, and political stability are not at all obvious, especially in the case of China. These relationships merit much more thorough examination than this conference gave them.

Many observations ran counter to conventional wisdom. For example, several speakers challenged the popular impression that China and India are far surpassing the United States in producing advanced-degree graduates of world class caliber in science and technology. In fact, all three countries may be facing a shortage of talent. Education quality, rather than quantity, will likely be the most important driving force in innovation. Shortfalls in India's professoriate and higher education system, apart from elite technical institutions, are well known and will require not only the added investment recently announced by the government but also new models of learning and instruction, as Sam Pitroda noted in his keynote address. The diasporas of both China and India, people who have studied, staffed and started businesses abroad, will be important drivers of change and adaptation. It is expected that improving research and economic opportunities will induce more of these assets to return home. A large proportion of those who remain abroad are developing close relationships with indigenous enterprises in their countries of origin.

Venture capital investment, particularly in China, has matured and focused on domestic markets, contributing to the growth of indigenous innovative firms. Increasingly, foreign (especially U.S.) investor partnerships are active in both China and India. India has more mature financial markets but also more restrictive labor rules. For international firms, complex legal structures in the two countries entail a greater reliance on legal services and greater regulatory risk. Both countries lack transparency in debt disclosure and impose restrictions on investment options. As market infrastructure improves and allows investors to price risk, demand and supply in venture-capital markets will grow. Growth in consumer demand can create further investment potential and help drive innovation.

In contrast to a generation ago, the private sector accounts for a growing share of R&D investment in both countries. Still, weak linkages between private and public sector R&D institutions hamper innovation. This is compounded in some sectors by the dominance of state-owned or quasi-governmental companies. Although no clear example of global technical leadership has yet surfaced in either country, areas of strength are clearly emerging. Sectors where China can make particular contributions to global science and technology include biology and Chinese medicine, nanotechnology, space science and technology, and energy, including cleaner technologies.

India holds strengths in product, component, and process design, pharmaceuticals, and automobile and aircraft parts.

Legal frameworks for innovation have undergone major changes in the past 10 years and are still evolving. Intellectual property systems in both countries have evolved toward international standards, although weaknesses remain. In China the enforcement system lags behind modernization and expansion of the patent administration system. India's patent system is experiencing backlogs and delays. China recently enacted a new anti-monopoly law and is making a major effort to develop and promote its own technical standards in the IT sector. There is some ambiguity about the extent to which either or both of these developments and others such as the recently announced government procurement policy will be applied to favor indigenous firms over multinationals and foreign competitors.

U.S.-based multinationals are investing heavily in China and India, including in R&D operations, although in most cases on a larger scale in China. Some of these affiliates work to adapt proprietary designs to local markets; others are working at the technological frontier on advanced products for world markets. The inducements to expand operations in the two countries are diverse – less expensive skilled labor, market access, opportunities to collaborate with world class scientists and engineers in academic and research institutions, and government grants and tax concessions. China has a more developed policy of subsidizing enterprises to promote regional economic development. In India, geographical dispersion is hampered by inadequate infrastructure. In both cases, there is a lack of experienced native-born managers.

Within China and India there is ambivalence about the role of international firms. They are seen as contributing to the broadening and deepening of the overall level of technology in the economies, but they are also suspected of monopolizing key technologies, crowding out opportunities for indigenous firms, and siphoning off top talent. Multinationals are responding to pressures to follow a more collaborative innovation model. Representatives of US-headquartered global firms emphasized the high level of labor turnover, making skills available to local enterprises, but they also acknowledged a tension between sharing of intellectual property to facilitate collaboration and building capabilities of indigenous firms that become competitors.

Four breakout sessions addressed recent changes in innovation capacity in important sectors of the Chinese and Indian economies—information technology and telecommunications, transport equipment, pharmaceuticals and biotechnology, and energy.

A theme of the IT session was the importance to innovation of a proximate population of highly skilled users. Although Chinese and Indian IT firms are gaining in scale and scope and certainly in manufacturing capability (for example, in semiconductors and personal computers), significant innovation, especially in software, is handicapped by the lack of a sophisticated customer base compared to those of the United States, Europe, and Israel. However, this gap may close within a decade or two.

Both China and India have ambitious plans to upgrade and expand domestic aircraft and automotive industries and become significant players in global markets. A key factor in both countries is the growing sophistication of engineering and design services, from fuselage design and avionics to passenger car platforms. The movement of design services to both countries has in large part been a function of cost differentials; but increasingly, it reflects a pursuit of talent. The Chinese and Indian automobile industries have moved from copying western designs to licensing technology and joint venturing with multinational companies (MNCs). The growing emphasis on indigenous innovation is illustrated by the Tata low-cost car for mass markets with wide income disparities. To become a significant supplier to western markets, the Chinese industry will have to overcome fragmentation and lack of brand identification.

As in other sectors, the roles of Chinese and Indian firms in pharmaceuticals and biotechnology reflect partly the breakdown of the self-contained innovation chain in western multinationals and partly the long-standing strengths in particular research, development, and manufacturing segments. This phenomenon is represented by the involvement of indigenous enterprises in early stage research, laboratory services, and especially clinical trials. In India, the evolution of the intellectual property regime for pharmaceuticals has fostered strength in process technology and manufacturing, evident in the growth of the generic pharmaceutical industry. Now some of those firms are venturing into the development of innovative products. China has opportunities to capitalize on knowledge of traditional medicines and on a rapidly growing biomedical research enterprise to contribute to the development of new pharmaceuticals.

Energy production in China and India was discussed in the context of two forces—on the one hand, rapidly growing demand fueled by domestic economic growth and, on the other hand, international pressures to reduce greenhouse gas emissions to decelerate global warming. In China demand has been met largely by expansion of coal-fired power generation capacity at an unprecedented rate. In the future there is prospect for some diversification, with nuclear, hydro and wind power playing a greater role. Accounting for a large share of the world's new power generation capacity over the next few decades, China is poised to become the lowest price producer and therefore the global manufacturing base for energy technology, which could include clean coal technologies as well as alternatives to fossil fuels.

Although the conference revealed few, if any, examples of Chinese- or Indian-origin globally important next-generation products or services, it was acknowledged that that may have been a function of hindsight or the selection of industries for discussion. Regardless, most participants agreed that as a function of their sheer size and dynamism, the Chinese economy in the near term and perhaps the Indian economy in a somewhat longer timeframe will have a much more profound impact on the United States than did Japan's growth in the 1980s. Participants were less clear about how the United States should respond other than to place a much greater premium on improvements in education, expansion of research, access to foreign-born talent, international collaboration, and strategic planning in an environment of rapid change.

1
India and China in the Global Economy

The economies of India and China have grown rapidly over the past couple of decades, and it is widely accepted that these two emerging giants will transform the global economy in numerous ways over the coming decades. Despite the importance of these countries, their strengths and weaknesses, the sources of their growth, and the missing ingredients to sustain high growth rates—are not widely known. Thus the first session of the conference, "India and China in the Global Economy", was devoted to providing the background necessary to understand what is happening in the two economies today and how they are likely to evolve in the future.

The speakers in the session, which was moderated by STEP board member David Morgenthaler, made it clear that although the economic growth of India and China has indeed been impressive, it has also been uneven, with some economic sectors developing more rapidly than others. Understanding the two countries' capacities for innovation demands a closer look at which areas have grown and which still lag. The speakers further agreed that it is a mistake to think of the growth of the two countries as essentially similar. Patterns of economic development in India and China are quite different, and this has an important bearing on forecasts for the two economies and, for that matter, strategies for dealing with the two countries.

THE ECONOMIC SITUATION IN INDIA

Arvind Panagariya of Columbia University opened the first session by outlining India's departure from a history of restrictive policies on investment, licensing, and production, which were especially tight in the 1960s and 1970s. Since liberalization began in the 1980s, GDP growth has surged. Panagariya suggested that the elephant metaphor did not reflect the recent speed of India's transformation, which has been more like a tiger. From 2003-2007, GDP growth has averaged 8.6 percent (14-15 percent in real dollar terms). Is this rate the peak of a cycle or can it be sustained?

Panagariya suggested that India's growth would continue and increase in the coming decade if economic reforms continue and are expanded and large-scale structural changes are undertaken to support growth. Exports have doubled in three years, and software exports doubled in the last two years. The exports-to-GDP ratio is "extremely low," he said, even though huge increases in foreign investment—over $21 billion—are comparable to that seen in China. India can adapt quickly, as evidenced by India's telecommunications revolution. From 5 million telephone lines in 1991, India now has over 200 million lines.

India's demography will very likely help sustain this growth. India's population is younger than China's and is exhibiting a rising rate of personal savings. Problems include a reliance on capital-intensive manufacturing, with labor-intensive manufacturing lagging. India still needs reforms in two areas in particular:

- Labor market inflexibilities limit firms' ability to respond to changing workforce needs; and
- The power sector remains unreliable throughout the country

The Indian government is moving on transport issues, but power shortages remain a bottleneck to growth. With a heterogeneous population and cultural variety, India does well in sectors where product differentiation is required and less well in industries that require scale.

THE ECONOMIC SITUATION IN CHINA

According to Nicholas Lardy of the Peterson Institute for International Economics, scale is a key difference between the two countries. Contrary to popular impression, China and India are not comparably sized global giants. China's trade is six times larger than India's. Even more striking, the increase in China's trade level in 2007 ($433 billion, valued using MER) was greater than India's total trade. India's share of the global economy today is still less than half of what it was at independence in 1948. India's economy is expanding rapidly; but its trade is still less than 1 percent of the global total, whereas China's trade is the second or third largest. A similar disparity exists in foreign investment.

For these reasons, Lardy expressed more optimism about China's growth than about India's. The competitive environment in China is more favorable and intense than it is in India, where certain sectors are protected from import competition. In China, with reduced tariffs domestic firms face competition not just from foreign imports but from foreign firms operating in China. China spends three times as much on infrastructure as India.

China's main challenge is to rebalance its growth strategy, moving toward one that relies more on domestic demand and less on exports. Currently, household consumption is only 36 percent of GDP, whereas in India that figure is 50-60 percent. For sustained economic development, India needs more manufacturing, a more liberalized trade environment, and more flexible labor markets.

The conventional wisdom is: "India does software; China does hardware. Those are their paths to expansion." But China's hardware exports are growing much faster than India's software exports, which make up less than 5 percent of India's GDP. India will need to take advantage of relatively low wage rates to build up its labor-intensive manufacturing sectors.

COMPARING THE TWO COUNTRIES

Sean Dougherty of the Organisation for Economic Co-operation and Development (OECD) Secretariat presented findings from two recent OECD surveys of China and India, highlighting sources of growth, productivity, and regulatory reforms.

Rooted in the dramatic shifts of the 1980s, growth in both countries is sustainable, but Dougherty drew some distinctions between them. Total Factor Productivity (TFP) growth rates are important. Capital deepening—that is, an increase in capital intensity, usually measured as capital stock per labor hour, also plays a dramatic role in growth, especially in China, and is the "major explanatory factor" in the differences between the two countries' per capita annual growth. India averaged 4.8 percent between 2000 and 2005, about half of China's 8.1 percent annual per capita GDP growth rate (Figures 1 and 2). This difference is also seen in the R&D expenditure differences: R&D intensity in India is <1 percent; in China it is 1.4 percent (Figure 3).

Research outputs are a better measure of performance than inputs. Although there are no good measures of scientific outputs, and there is considerable uncertainty about international comparisons, a common output measure is publications in leading peer-reviewed journals with contributions worldwide. In 10 years from 1995 to 2005 Chinese articles in high-impact scientific journals increased more than 16 times, while Indian articles merely doubled (Figure 4).

India has competitive costs and wage levels, but it needs larger-scale firms to compete successfully. Dougherty confirmed the observation that labor market restrictions in India are that country's greatest challenge. At the state level, though, India is deregulating and making labor markets more flexible. In China, where private firms are more productive than public firms, there is a great need to extend privatization. China is restructuring rapidly and deepening regional specializations.

India's financial markets are more developed than China's but India has a greater need to reduce regulatory restrictions in financial product markets. Currently, India has far more restrictions than any OECD economy. With fewer restrictions, China has managed to be more flexible in supporting new, higher risk, technological developments.

Education outcomes in India are improving, approaching China's. In GDP growth, China's demographic dividend will tail off in the next 10 years, while demographic rates in India will promote savings growth. Despite their problems, the future looks bright for both economies.

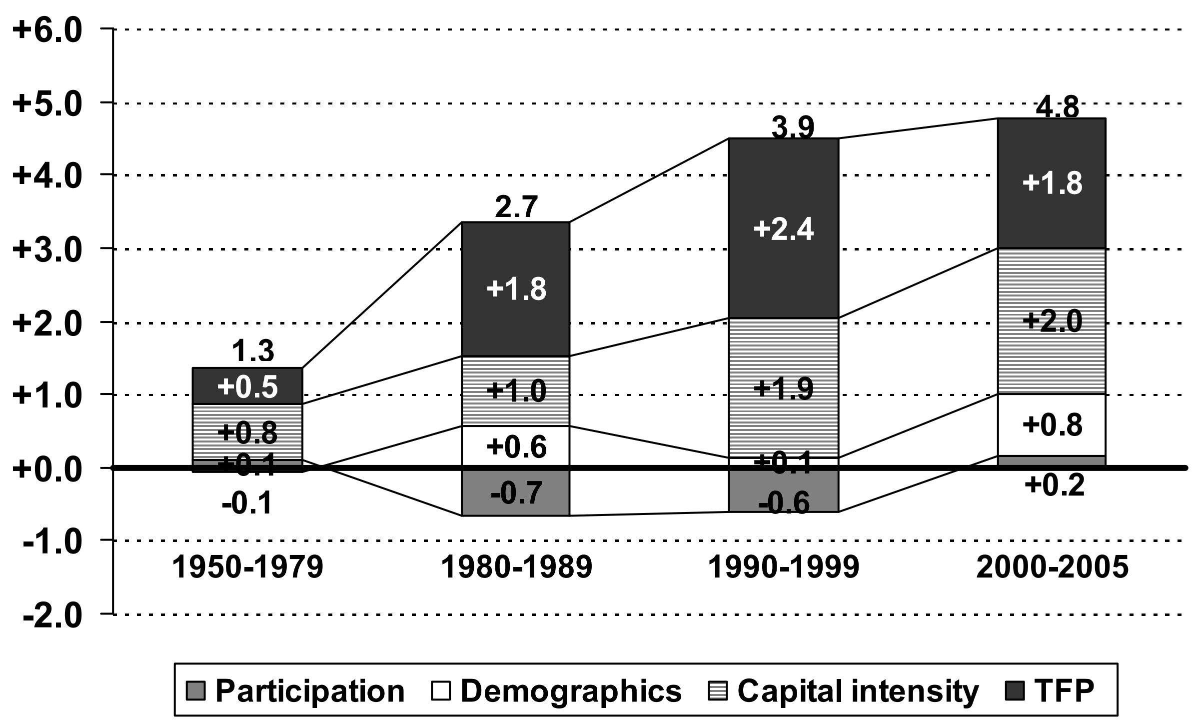

FIGURE 1 Sources of India's per capita GDP growth (% annually). (Participation: the effect of the participation rate; Demographics: the effect of the share of the population of working age; Capital intensity: the effect of the level of capital per worker; TFP: total factor productivity.) SOURCE: Dougherty.

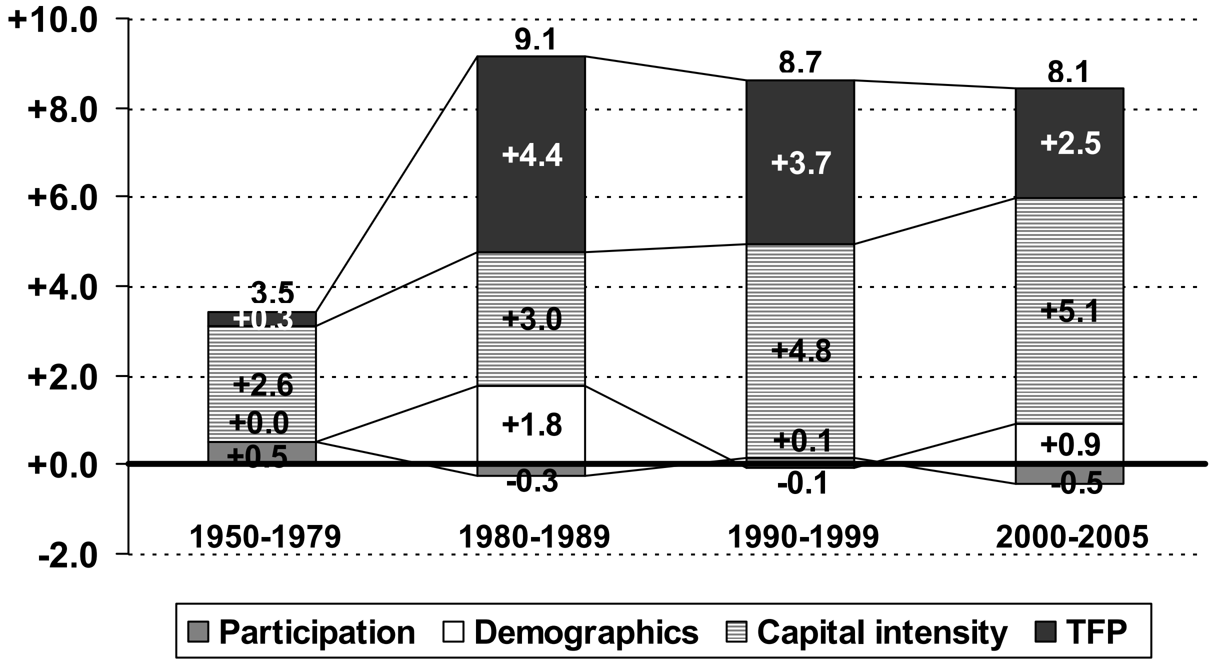

FIGURE 2 Sources of China's per capita GDP growth (% annually). (Participation: the effect of the participation rate; Demographics: the effect of the share of the population of working age; Capital intensity: the effect of the level of capital per worker; TFP: total factor productivity.) SOURCE: Dougherty.

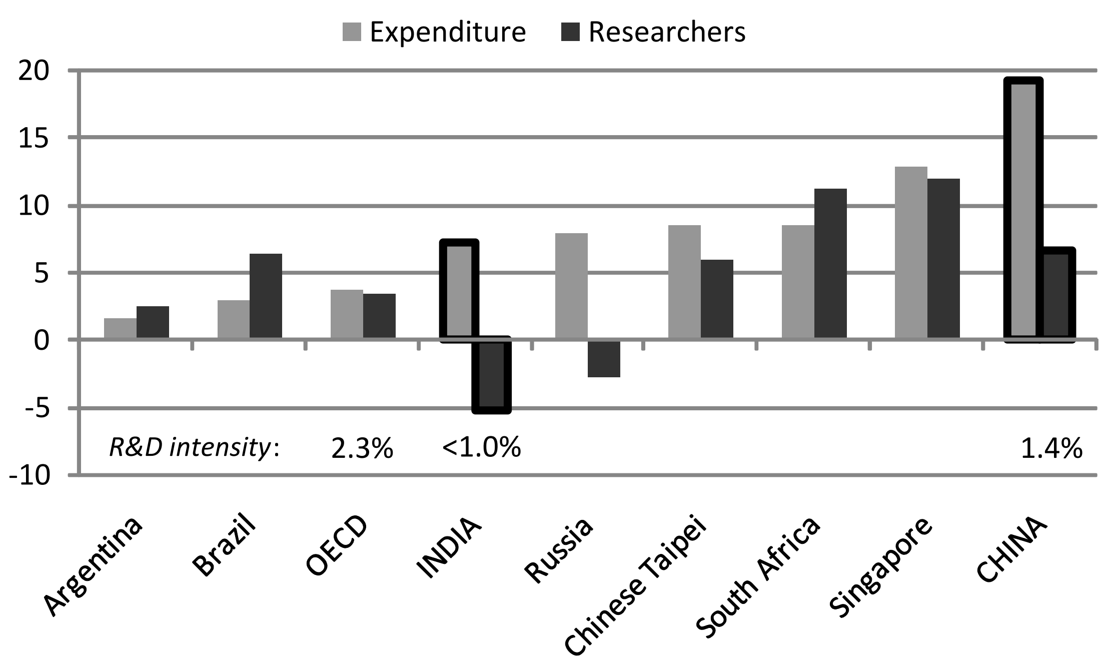

FIGURE 3 R&D Expenditures and Researchers (% annual change 1995-2004) SOURCE: Dougherty

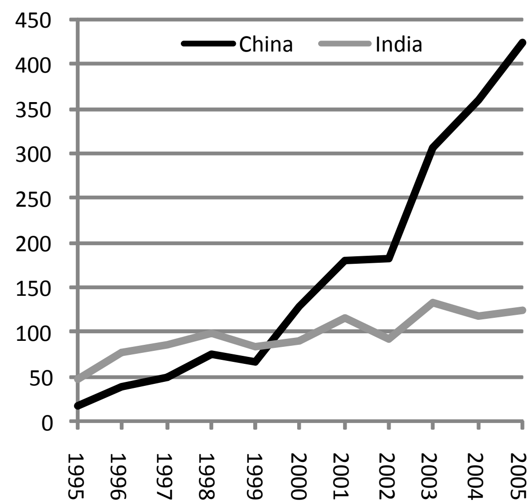

FIGURE 4 Articles published in high-impact journals. SOURCE: Dougherty

DISCUSSION

Responding to a question on the state of innovation in both countries, Panagariya said that India was still "well inside" the technological frontier. Dougherty considered both economies to be inside the frontier. The growth rates shown above (Figures 1 and 2) represent a measure of innovation. By some measures, China's R&D expenditures are high, but it is very hard to assess the real state of innovation.

To what degree do we need to look at society-wide structures and legacy issues, asked Marco di Capua, U.S. Department of Energy representative in Beijing. How does innovation change society structures themselves? One factor is intellectual property rights protection, but there are different sides to that issue. In China, a vigorous sharing of ideas is the flip side of fairly lax intellectual property protection. By that same token, some argue that intellectual property protection in the United States may have gone too far, hampering innovation.

In terms of quality of life, a questioner asked, did disregard for environmental safeguards in the early years of China's growth allow the economy to grow unimpeded? As its leaders become attuned to environmental issues, will growth slow down? Over a third of China's population lacks access to clean water. Yet the focus on growth will probably not change in the next three to five years, Lardy replied. With China's per capita income at $1,600 (measured at MER), the country is unlikely anytime soon to institute the same environmental measures as OECD countries.

In response to another questioner, Panagariya cited three factors in rebutting pessimism on India's long range prospects for developing an innovative economy:

- India's history of democracy over the past 60 years gives it a foundation for stability and adaptation, while China faces an uncertain political transition in the coming years.
- India's demographic dividend is much greater than China's.
- Assuming that ultimately rapid growth slows down, India's experience of high growth is more recent, while China's may sooner run its course.

2
What is the United States' Interest?

No one disputes that the rise of China and India as technological powers with huge populations and internal markets, more highly educated scientists and engineers than any other country in the world, and sophisticated military forces will profoundly affect American interests. But exactly how? What U.S. interests are at stake? How do national interests diverge from those of U.S.-headquartered global companies? Questions such as these must be addressed before we can consider how the United States should respond to the growing challenge from these countries.

Norman Neuriter, former State Department science adviser, co-chair of the Indo-US Science and Technology Forum, and scholar with the American Association for the Advancement of Science, moderated a conference session devoted to these questions. Other contributors to the discussion included Tony Hey, chief of Microsoft Research, Kent Hughes of the Woodrow Wilson International Center for Scholars, and Da Hsuan Feng of the University of Texas at Dallas and the National Cheng Kung University, Taiwan.

Tony Hey described Microsoft's investment in research in Central and South Asia, first in China in November 1998 then India in January 2005. The Microsoft unit in China has seen 50 percent growth, hiring 120+ staff members in FY 2006 and creating links with universities, including nine joint laboratories. Total employment of locals with technical qualifications is more than 300. Although smaller,—employing 50 full-time staff and 100 interns—the company's Indian operation builds on that country's tradition of education and set of research challenges. Both operations have become integral parts of the company's worldwide research and development activities.

Kent Hughes compared the challenge of China and India to the Russian launch of the Sputnik satellite, 50 years to the week earlier. Sputnik was seen as a challenge to U.S. technological dominance, particularly in the military sphere. It helped spur investment in science and engineering education and private sector innovation. Will the challenge of China and India's growing economic strength and technological capacity prompt a similar U.S. response? "Innovation has gone global," said Hughes, forcing the United States to change its role to one of adapter as well as lead innovator.

Hughes observed that the United States has long enjoyed a pool of domestic technical talent and an inflow of foreign talent. The emergence of a global skilled labor pool able to cooperate and compete at a distance as well as migrate from one location to another have benefited the United States and other countries enormously. They also present a conundrum, however, as low salaries in India and China bring competition. In this context, India and China could define wage rates for professionals everywhere, creating disincentives for native-born students to pursue careers in science and engineering.

The global talent pool represents a particular challenge for U.S. national security agencies, which are restricted in their ability to engage world talent. In recent years, growing difficulties in getting U.S. visas for scientists from abroad to attend conferences have driven some U.S. growth abroad. The United States should consider the emergence of a global talent pool as a positive competitive challenge and catalyst. Fifty years after Sputnik, are we meeting our next Sputnik challenge? In Hughes' view, emerging capacity in China and India underscore a need to reevaluate the strengths and weaknesses of our innovation system anew.

Da Hsuan Feng, University of Texas at Dallas and Senior Executive Vice President for Research at the National Cheng Kung University at Tainan, Taiwan, outlined a future scenario based not on triadic competition among China, India, and the United States but rather envisioning a political and economic convergence of China and India. In his talk, "Googling My Late Father," he described his long connection to India, having been born in New Delhi in the 1940s to a journalist based there. Many years later, he came across a published interview between India's Prime Minister Jawaharlal Nehru and his father, in which Nehru voiced his hope that India and China would move forward together. The rift between the two countries in the 1950s was a great disappointment to Nehru. Now, the increase in international commercial activity and the growing middle class in both countries will drive demand for better health care, environmental quality, and quality of life.

A European Union was scarcely imaginable amid the ruins after World War II, said Feng. In the same way we may be surprised by a convergence of interests in Asia. He posited a future train ride from Seoul to Mumbai that would not require passport checks, just as Europeans now travel from Helsinki to Rome, the result of increasingly shared interests.

3
Human Capital Development

In countries such as China and India that are seeking to aggressively expand their economies and their capacity for technological innovation, a key limiting factor is human capital. Are there enough competent scientists and engineers to support that growth? Enough technicians? Enough managers who understand technology?

In opening a session on human capital development, moderator Pete Engardio of *BusinessWeek* said that with the recent dramatic growth of the technological sector in those two countries, companies—both foreign-owned and domestic—are running into a number of practical problems. One of them is that the skilled workforce in those countries is not as unlimited as many had assumed. “Although China and India have, no doubt, tremendous raw talent, a lot of questions are being raised now about the quality of this talent and how prepared Indian and Chinese engineering graduates are for global work.” Retention is also becoming a difficult problem, as wages in many fields of engineering are skyrocketing, particularly in India. And China faces an acute shortage of managers who are able to work effectively in multinational corporations. How China and India deal with such issues will have great influence on how well and how quickly the two countries develop their capacity for innovation.

HUMAN CAPITAL IN INDIA

V.S. Ramamurthy of the Indian Institute of Technology in New Delhi and co-chair of the Indo-U.S. Science and Technology Forum described the Indian challenge as a tension between increasing the number of premier educational institutions and addressing social obligations. The Indian government recently announced a plan to invest $133 billion in education over seven years, with private investment in higher education growing as well. He suggested that the growth of public and private investment will somewhat ease pressures on India’s educational system. Student intake is growing slowly; lab infrastructure is weak but the key constraint may be faculty shortages. Compensation packages for teachers cannot compete with the private sector, and the time required to launch an academic career is much longer than that to prepare for a career in industry. Ramamurthy called this lack of highly qualified faculty “a disaster in the making.” India has the demographic advantage mentioned earlier but faces challenges in its institutional structure for education. The Indian diaspora may be able to play a role in closing this gap.

Devesh Kapur of the University of Pennsylvania offered an equally sobering assessment. As enrollment rates have risen, state funding for education has stagnated; most growth has come from the private sector. Higher education institutions in India suffer from mediocrity and heavy politicization, restrictive centralized control, and endless litigation over policies. The market for talent is global, so the low salaries for Indian faculty will not draw foreign or domestic talent to that market. The fact that the system functions reasonably at all well is due to the “Darwinian struggle” for entry into the best Indian institutes of technology (IITs). An IIT graduate can make a better living by coaching applicants for IIT entrance exams than as a senior member of the IIT faculty. “Most learning in India,” Kapur said, “is not from your teachers but from your peers and yourself.” To address the overall deficiencies of Indian higher education, large firms have created in-house corporate universities.

In seeking education abroad, there has been a shift away from U.S. universities toward Australia and Singapore as a result in part of U.S. immigration rules and practices. Unlike their counterparts in the 1950s, who returned from abroad for careers in the public sector, most contemporary graduates return to positions in the private sector. Belatedly, the government has stepped up education funding with the fourfold increase referred to by Ramamurthy, but that is designated primarily for "hardware" upgrades. Faculty shortages will almost certainly persist.

It is true, Kapur observed, that the pool of talent going to college will increase, not only with the growing population but also with a higher percentage pursuing higher education. But higher education will continue to be politicized and its deficiencies could even precipitate a constitutional crisis.

INTERNATIONAL PERSPECTIVES ON HUMAN CAPITAL

Vivek Wadhwa, an entrepreneur affiliated with Harvard School of Law and Duke University, has studied the supply of researchers and graduation rates in the United States compared to the surges in graduates produced in India and China from the perspective of U.S. access to human capital. Wadhwa concluded that China is indeed racing ahead of both India and the United States in producing master's degree holders in science and engineering. In 2002 it surpassed the United States in producing PhDs in computer science, engineering, and IT. Nonetheless, the notion of a U.S. engineering shortage is a myth in his view. On the value of a conventional four-year degree, studies showed that companies were hiring engineers with two- and three-year degrees and training those employees themselves. "Bachelor's degrees don't even matter," Wadhwa said.

Wadhwa found in his surveys that companies go offshore for reasons of "cost and where the markets are." Meanwhile, Asian immigrants are driving enterprise growth in the United States. Twenty-five percent of technology and engineering firms launched in the last decade and 52% of Silicon Valley startups had immigrant founders. Indian immigrants accounted for one-quarter of these. Among America's new immigrant entrepreneurs, more than 74 percent have a master's or a PhD degree. Yet the backlog of U.S. immigration applications puts this stream of talent in limbo. One million skilled immigrants are waiting for the annual quota of 120,000 visas, with caps of 8,400 per country. This is causing a "reverse brain drain" from the United States back to countries of origin, the majority to India and China. This endangers U.S. innovation and economic growth. There is a high likelihood, however, that returning skilled talent will create new linkages to U.S. companies, as they are doing within General Electric, IBM, and other companies.

Jai Menon of IBM Corporation began his survey of IBM's view of global talent recruitment by suggesting that "multinational" is an antiquated term. IBM pursues growth of its operations as a global entity. There are 372,000 IBMers in 172 countries; 123,000 of these are in the Asia-Pacific region. Eighty percent of the firm's R&D activity is still based in the United States. IBM supports open standards development and networked business models to facilitate global collaboration. Three factors drive the firm's decisions on staff placement and location of recruitment -- economics, skills and environment. IBM India has grown its staff tenfold in five years; its $6 billion investment in three years represents a tripling of resources in people, infrastructure and capital. Increasingly, as Vivek Wadhwa suggested, people get degrees in the United States and return to India for their first jobs.

IBM follows a comparable approach in China, with 10,000+ IBM employees involved in R&D, services and sales. In 2006, for the first time the number of service workers overtook the number of agricultural laborers worldwide. Thus the needs of a service economy comprise an issue looming for world leaders.

HUMAN CAPITAL IN CHINA

Cong Cao of the Levin Graduate Institute of the State University of New York painted an unconventional picture of China's education system and talent challenge. Despite the very large numbers of science graduates frequently reported, Cao suggested that China, too, has a relatively low percentage of students going into science and technology, and there is insufficient business investment in training. China's leader Hu Jintao recently pronounced that innovation will drive China's future development and determine the success of efforts to meet energy, environmental protection, and public health needs. That puts a premium on accelerating the development of human resources. A recent Levin Institute study concluded that China faces a shortage of more than 250,000 qualified people, especially in the highly skilled segment of the labor pool. The looming talent shortage has its roots in the Cultural Revolution of the late 1960s and 1970s, the brain drain of the 1970s and 1980s, and the population's aging.

KEYNOTE

At the beginning of his remarks, Satyanarayan "Sam" Pitroda of the Indian National Knowledge Commission and WorldTel, Ltd., observed that his personal history reflects the power of innovation and international networks. Raised in a tribal area in Orissa and the first member of his family to get more than four years of schooling, Pitroda graduated from college, pursued higher education in the United States, and developed his entrepreneurial skills here before returning to India to work with Prime Minister Rajiv Gandhi in the 1980s to assist in developing a robust telecommunications industry in an inhospitable policy environment. The dragon and the elephant are as different as the Yellow and the Ganges Rivers. The conventional view, he said, is that China is focused on manufacturing and is far ahead in that field while India is focused on services and is lagging in manufacturing. That impression is partly true, but it is also partly mistaken. Then he set out to provide an up-to-date description of Indian innovation that would dispel some of the misconceptions about that country.

Called upon by the current Prime Minister, Manmohan Singh, to help improve Indian higher education and relieve skill shortages critical to economic growth in the 21st century, Pitroda agreed to head the Indian National Knowledge Commission, charged with making policy recommendations to enhance Indians' access to knowledge, contribution to knowledge creation, and facility in applying knowledge. The Commission's recommendations address higher education, science and technology training, libraries, digital networks, and vocational education, as well as E-governance at all levels.

Acknowledging earlier speakers' observations, Pitroda said that issues in education are highly political and progress in addressing them requires reform within the government. But he expressed optimism for India's capacity to address those challenges, pointing to its transformation in the IT sector, which 20 years ago faced comparable hurdles. Three main issues are:

- Disparities in wealth.
- Uneven development: "We are creating billionaires, but we don't have power 24 hours a day."
- Demography: India's 500 million citizens under the age of 25 represent "the workforce of the world."

The Indian government is responding to the question of how to create jobs by pledging at a recent Planning Commission meeting to quadruple the public investment in education over the next five years relative to the previous five years. This will involve establishing 30 new universities, 6,000 new schools and 8 new IITs (Indian Institutes of Technology). "We also recognize it is not about hardware," said Pitroda, "but about software" -- addressing the critical need for qualified teachers. For that, India needs to change the teaching paradigm, from blackboard and chalk to new media.

Surplus optic fiber installed in recent years will be used to connect schools and enhance educational delivery systems. In view of the fact that India cannot deliver enough "software," the role of teacher will change to something more like mentoring. In addition, basic assumptions of the education system are being questioned: why does a B.S. degree require four years? How can space on a university campus, where many classrooms are often unfilled, be better used? The debate has already begun, aided by India's democratic platform.

The Knowledge Commission's main priority is improving primary education, but higher education is also critical and may need to be handled differently. For example, the Indian government recently raised quotas for lower caste students in primary schools, but in higher education quotas would entail letting quality suffer. In this respect the Knowledge Commission emphasizes "a process of change, not a product," Pitroda said.

To address inequality in development, India needs first to identify new measures of economic health and growth. "The models of the past don't make sense," Pitroda said, including measures used for decades by the World Bank. Second, India needs to incorporate human capital development in measures of national health and economy. Third, India needs to reform its intellectual property (IP) rights system. "It's very painful to get a patent in today's IP system," said Pitroda. The delay in processing patent applications has increased and the need for translation of applications has resulted in duplicated effort and higher cost. "Basically, the message to would-be creators and entrepreneurs is, 'Don't invent.'"

The Commission's recommendations on IP policy support a single open international platform for intellectual property protection. The system would determine within a year whether the applicant has an invention or not. After that, opportunities for challenges to a patent would be limited. As a result, patent owners would be more certain about the extent and reliability of their IP rights.

In creating these new models of education, health, and intellectual property, India needs to change long-held perceptions. Pitroda underscored the difficulty with a story about a Texas farmer's visit to an Indian village, where he asked a small farmer, "How big is your farm?" The local farmer pointed out the limits of his land – about an acre, bounded by tree, stone, and building. In turn he asked the Texas farmer, "How big is your land?" The Texan pondered how to reply in meaningful terms and answered, "If I start out driving at 6 a.m. at one end of my farm, it can take me 18 hours to reach the other end." The Indian farmer considered the answer for a few moments and responded, "I had a car like that once, too."

Asked by a member of the audience about the scope for and rate of change in a democracy versus an authoritarian system, Pitroda said if the goal is swift change on pre-determined lines, authoritarian systems can respond well; but democracy is better suited to bringing about change where the goal is more far-reaching improvement in the quality of life. Will rapid technological change convince hundreds of millions of Indians not engaged in technology of the benefits of globalization? Pitroda replied, the answer lies in part in how we communicate about the issue. Today "globalization" is widely seen as an attribute of multinational corporations not conducive to improvements in the general population's quality of life. It needs to be communicated that globalization also means open platform development and collaboration among agile teams bringing widely shared benefits.

4
Capital Markets and Investment

The availability of seed, angel, and venture capital is a key factor in the creation and growth of businesses involved in the development of innovative technologies. In the United States and other developed countries, early stage investors in particular have played an important role in nurturing firms that have new and innovative products and services to offer. As companies grow, debt capital becomes more important, especially for investment in research and development. Thus, in assessing the potential for the development of innovative capacity in China and India, it is important to take into account the condition of capital markets in those countries. David Morgenthaler led a discussion of this topic by a panel that included Martin Kenney of the faculty of the University of California at Davis, Oded Shenkar of Ohio State University, Lee Ting of W.R. Hambrecht and Lenovo Group Ltd., and Sandra Lawson of Goldman Sachs.

VENTURE CAPITAL IN CHINA AND INDIA

Venture capital (VC) industries in India and China are quite immature and were led initially by international development agencies and government agencies, observed Martin Kenney. The first significant interest in indigenous technology-based firms came in the dot-com boom in the late 1990s. China took off rapidly, with excellent NASDAQ public offerings and acquisitions by established firms beginning in 2003. India has seen successful U.S. stock market exits for private equity. India also has the advantage of a vibrant stock market. China has experienced many more venture capital investments than India, focused on the domestic market. Venture capital in India has both global and domestic market investments.

TABLE 1 Total Venture Capital Investment ($ Billions) in Five Key Global Nations/Regions, 2002-2006.

Year	China	India	Israel	Silicon Valley	Boston
2002	0.4	0.2	1.3	7.6	3
2003	2.4		1	6.8	3.1
2004	0.6	0.3	1.4	8.3	2.9
2005	1.2		1.3	8.5	3.1
2006	1.9	0.5	1.4	9	3.1

SOURCE: Adapted from *Global Venture Capital Insights Report* (2007) Ernst & Young

A look at regional VC investments (Table 1) reveals the predicted concentrations--in Beijing and Shanghai in China and in Bangalore, Mumbai, and Chennai in India. One in three Indian VC firms had significant U.S. VC involvement. Many elite Silicon Valley VC firms are operating in China, such as Sequoia Capital International Funds. American venture capitalists are growing more comfortable with doing business in both countries and are learning the differences in their intellectual property systems. India's IP system poses fewer impediments (Figure 5).

Multinational VC firms are playing an important role in both countries although generally not on the frontier of technology, where U.S. VC firms are dominant. Exceptions are firms such as Softbank, 3i, and Jafco. Corporate VC funds, especially Intel Capital and Nokia, are also active. In China VC investments are generally larger, more mature, and geared mostly to supplying needs in the domestic market. In India, they are concentrated in

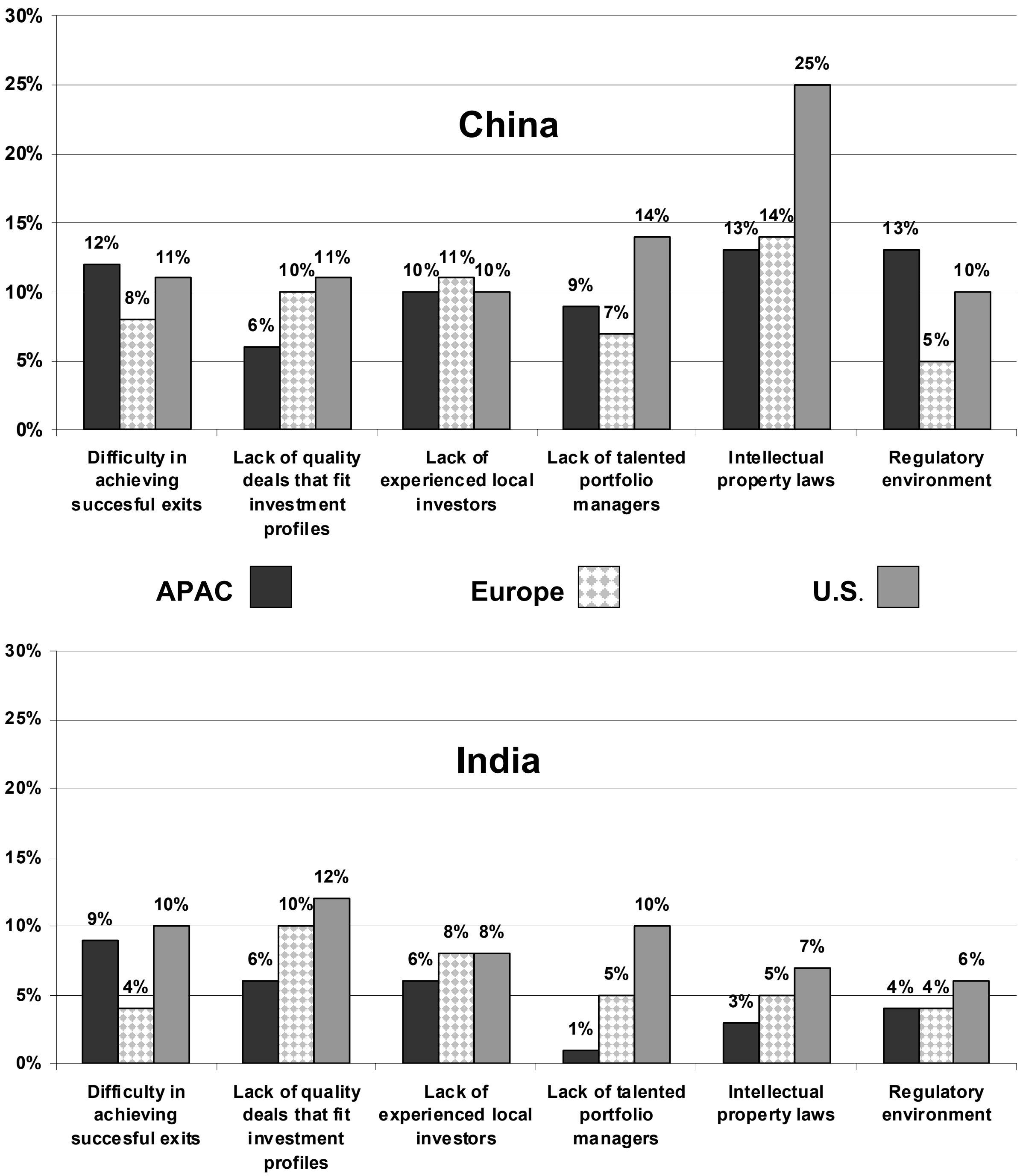

FIGURE 5 Major impediments to VC investment in China and India. Respondent groups are Europe, United States, and Asia Pacific (APAC). SOURCE: Adapted from *Global Trends in Venture Capital* (2007) Deloitte & NVCA

services and more oriented to the global market. It is possible that Indian venture capital could be more significant for global technology firms in five years, according to Kenney.

THE LINK BETWEEN EDUCATION AND CAPITAL MARKETS

Oded Shenkar explored the linkage between education and capital markets in China. Mattel Corporation's recent admission that U.S.-based design work, not China-based manufacturing, was to blame for their faulty toys was telling. How long will it be before Chinese manufacturers take on the design process themselves? The answer has huge financial implications, as design determines a large share of the value captured in exports.

China overtook the world in volume of IT exports but the largest share of those exports still belongs to foreign enterprises working in China. In 2005, MNCs were responsible for 58 percent of China's exports. The standard critique of Chinese innovation is that it has a long history of inventions but has not maintained flexibility for adapting its formulas. This critique dates back at least to de Tocqueville in the early 1800s.

Shenkar listed several challenges to successful innovation in China. The strategy of acquiring innovation, illustrated by the Lenovo acquisition of the personal computer division of IBM, has clear benefits for the mid-term. The strategy of attracting Chinese graduates back from abroad is also very likely to pay off. But government spending per student in China has not risen, and this points to difficulty in fostering indigenous innovation. Most Chinese universities are not on par with high-quality universities internationally; learning in China still depends mainly on repetition and memorization. There are weaknesses in both educational theory and practice in China.

Another challenge to foreign companies below the top rung in China is the vulnerability of their intellectual property to exploitation by Chinese competitors. Even in a knowledge economy, Shenkar concluded, it is possible to grow and profit by imitating without innovation.

CHINA'S VENTURE CAPITAL MARKETS

Lee Ting, a U.S.-based private equity investor who is also an official of the Lenovo Group, offered a practitioner's perspective on China's private equity markets. Ten years ago, he observed, U.S. private equity firms were not active in China; now we find all the large VC firms with a presence and investments in China.

What are the similarities and differences between the U.S. and China situations? In both, a private equity firm searches for companies with high value positions in a large market. Differences include the additional complexities in China, including a legal structure requiring a greater reliance on legal services, greater regulatory risk, and personal trust issues. How do you trust local management with venture money? An ability to identify the right person for a transaction is extremely important in China. The China market is still evolving. It lacks transparency, which China's regulatory agencies are working to improve. And the market suffers from the liquidity problems of an inefficient market. Still, the prospect is for more opportunities to invest, more successful exits for investors, and hence more multinational VC involvement.

DEBT MARKETS

Sandra Lawson of Goldman Sachs echoed Kenney's points on the long-term picture, but observed that while China outpaces India in foreign direct investment (FDI), India's foreign investment upturn is likely to continue (Figure 6).

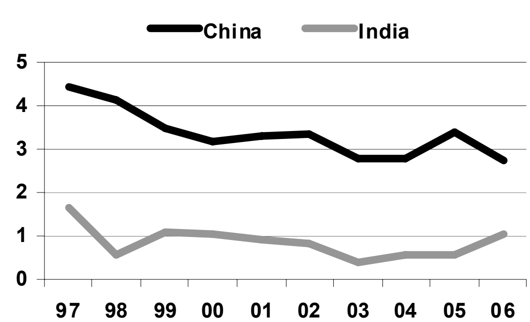

FIGURE 6 Foreign direct investment as a yearly percentage of GDP. SOURCE: Lawson

Across Asia, debt markets play a limited role in economic growth. They are small and dominated by governmental or quasi-governmental debt. A more robust corporate debt market is essential for economic growth and is the backbone for R&D investment. It enables companies and lenders to take more risk. At this point, however, the corporate debt market has little liquidity.

In both countries there are problems with respect to supply, demand, and marketplace infrastructure. In India, for example, there is little transparency. Companies disclose debts only to a few investors. Markets in mutual funds and pension funds are exceedingly weak. A good deal of investment could go there, but investors are restricted on where they can invest. For the most part investment is channeled to government debt. Investors have little ability to price risk, and they face unwelcome tax and accounting rules. Thus, debt markets represent a chicken-and-egg situation. It is a supply issue but also a problem of market infrastructure. If the infrastructure problem is addressed, both demand and supply will accelerate. India's Knowledge Commission is creating awareness of what is needed to grow innovation there, but the choices are politically difficult.

In Lawson's opinion, both China and India have strong prospects for growth of debt markets (Figure 7). In the slightly longer term by 2016, China's domestic debt market could grow to the size of today's U.S. market for Treasuries.

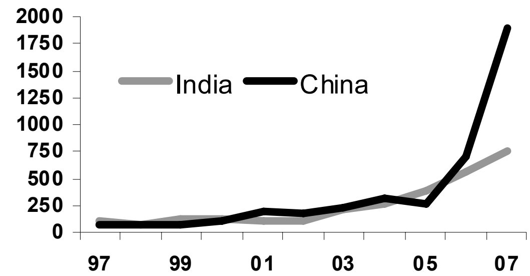

FIGURE 7 Domestic support underpins equity markets, as of September 2007 (USD Billions). SOURCE: Lawson

There is a need for larger investors to get things moving in that direction. Building a debt market now can fuel the growth of medium-size corporations over the long term.

Asked about the significance of the money flows associated with China's real estate boom, the panel said that the boom underscores the need for leaders to create a greater range of investment opportunities. Rising real estate prices do not create value *per se* and the bursting of the real estate bubble can have disastrous consequences for the economy as a whole. But real estate transactions do help grow a middle class, which in turn has broader positive effects. A growing mortgage market helps spread growth by creating demand for furnishings and related products.

5
Research and Commercialization Infrastructure

Innovation depends on a research infrastructure that generates and validates new ideas and a commercialization capability to take the creations of the R&D process and transform them into commercially successful products and services that generate a return on investment. In a session devoted to these conditions for innovation, moderator J. Thomas Ratchford of George Mason University introduced presentations on Chinese and Indian government plans for science and technology development by Mu Rongping, Chinese Academy of Sciences, and Venkatesh Aiyagari of the Indian Department of Science and Technology.

In describing the context of the discussion, Ratchford commented that globalization, having been enabled by science and technology, has in turn changed the practice of science and technology around the world, including in China and India. In contrast with 20 years ago, both countries now have large, growing economies. China has a gross domestic product (GDP) of between $2.5 trillion and $7-8 trillion, depending on whether it is estimated by the MER or PPP method, and India's is between $800 billion and $4 trillion. By comparison, the United States has a GDP of $13 trillion. China invests about 1.3 percent of its GDP in research and development, with about 67 percent coming from private investment, not far from the median for developed economies. India, by contrast, spends only about one-third as much—0.4 percent of its GDP—on R&D, with only 20 percent coming from the private sector.

Besides capital, Ratchford added, successful innovation also requires highly skilled technologists and managers. In this regard, both China and India are increasingly well-endowed with hundreds of thousands of well-trained people employed in R&D. China may lead India to some degree in R&D human capital, but both countries unquestionably have access to scientists and engineers trained at some of the best universities in the world and thus have resources for productive, internationally competitive research and development.

CHINA'S NATIONAL INNOVATION STRATEGY

Mu Rongping, addressed China's changing national innovation strategy. China's economic growth has been caused more by the low cost of labor and high investment than by innovation, he observed. China has insufficient investment in innovation, an unbalanced allocation of innovation resources, and too little R&D (Figure 8). That realization is now spurring a new development philosophy aimed at

- closing the large gap between the R&D capacity of leading universities and business enterprises;
- raising patent productivity in enterprises;
- raising research productivity as measured by publications and citations; and
- strengthening linkages among research institutions.

The central government's policies for building innovation capacity include

- increasing expenditure on science and technology to spur and maintain growth;
- instituting tax incentives in the form of deductions for technological development in enterprises;
- focusing government procurement on purchasing new products;

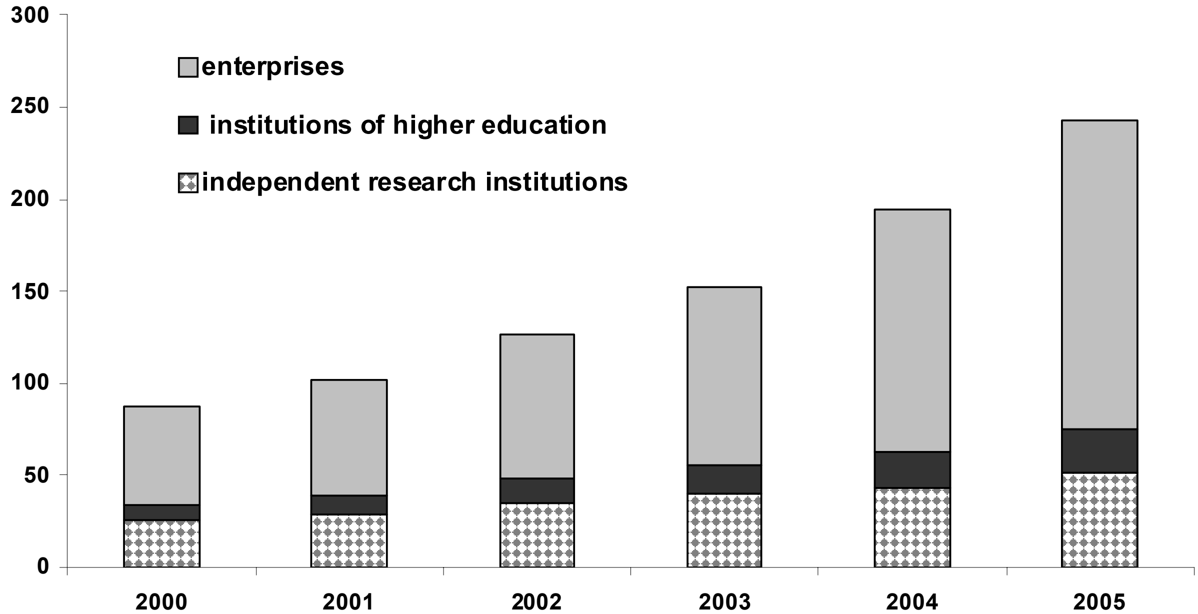

FIGURE 8 R&D expenditure in China (billion RMB Yuan) SOURCE: Source: Adapted from S&T Statistics Data Book (2001-2006) Chinese Ministry of Science and Technology

- providing direct financial support;
- encouraging adoption of imported, assimilated technologies; and
- enhancing protection of intellectual property rights with higher standards, faster processing of applications, better trained and qualified reviewers, and facilitation of the flow of patented technology to enterprises.

In addition to national government initiatives, localities have instituted incentives for science and technology investment, with the result that S&T expenditures have increased dramatically in most provinces, even since 2006. Nevertheless, a great many enterprises have yet to benefit from national and regional innovation policies, either because of a lack of awareness or because the rules for taking advantage of the incentives are complicated.

China's goal of becoming an innovation-driven country is highly ambitious. It depends on many factors including an innovation-friendly internal culture and effective foreign investment. Fields in which it is believed China can make a substantial unique contribution to global science and technology include biology and Chinese medicine, nanotechnology, space science and technology, and energy.

INDIA'S RESEARCH INFRASTRUCTURE

Venkatesh Aiyagari described India's changing research infrastructure. The driving factors in scientific innovation are investigators' passion for a discipline, for crossing intellectual boundaries, and for meeting society's needs. Early pioneers in Indian innovation focused on improvements in agricultural and dairy production, led by the TATA Institute of Fundamental Research (TIFR), and in space and satellite technology, led by the country's defense laboratories and Council of Scientific and Industrial Research (CSIR).

Today, recognizing that Chinese investment in R&D far outpaces India's, the country aims for faster and more inclusive growth, according to Aiyagari. Government plans focus on

- developing talent by inspiring students to pursue careers in science and technology;
- fostering creativity rather than rote learning; and
- ensuring that scientific and technical careers are secure and attractive.

In the 11th national plan covering a five-year period that commenced in 2007, India is endeavoring to triple investment in basic research while quadrupling overall investment in science. Earlier the government created the Fund for Improvement of S&T Infrastructure in Universities and Higher Educational Institutions (FIST), launched a program for research in nanoscale science and technology, and began to expand the network of Indian Institutes for Science and Research (IISERs) as well as the number of Indian Institutes of Technology (IITs). Although in its early stages, the nanotechnology initiative, while focusing on basic research, has involved industry in eleven centers of excellence.

In addition to public investment, the Indian government aspires to encourage growth in private investment, including by small and medium-size enterprises. The New Millennium Indian Technology Leadership Initiative, for example, includes a small business initiative in biotechnology with medical, agricultural, food, industrial, and environmental applications. The premise is that technology producers and users need to collaborate for innovation to address market needs and opportunities. Nevertheless, overall, Indian efforts to boost private investment have not been highly effective.

PANEL DISCUSSION

These presentations on Chinese and Indian S&T policies were followed by a panel discussion led by Denis Simon of the Levin Graduate Institute of the State University of New York. Simon observed that there is a wide divergence in views of Chinese and Indian progress among both western and native experts. Some emphasize the resurgence of activity and level of commitment and claim that China and India are making rapid progress in spurring innovation. Others draw sharp contrasts between the two countries, and still others focus on the distance China and India have to go to match western, especially U.S., standards. He asked the members of the panel to characterize their own views.

Defining innovation as the ability to develop and successfully market new products and services in the global economy, Carl Dahlman, Georgetown University professor and former World Bank official, observed that a variety of institutional and policy changes, such as liberalized trade policies, contribute to that capacity. Other conditions are holding each of the countries back. In India, he said, weaknesses in the educational system constrain the growth of the country's talent pool. He judged human resources in the information and computer technology field to be "quite shallow." Both countries have a long way to go, in Dahlman's view, before they become technology superpowers.

Harkesh Mittal, from India's Department of Science and Technology, highlighted India's diversity in climate, language, and culture, making it "a nation of nations." A tension exists between the stability that is politically desirable and the disturbance required for change and growth. In Mittal's view, at least for the time being, India, has achieved an equilibrium that is contributing to economic momentum. He cited the example of an Indian nanoscientist participant in the Global Innovation Challenge held in Berkeley, California. He brought artificial flowers whose fragrances were so real that he was detained temporarily by U.S. Customs for bringing in banned botanical samples. Another example he cited was an Indian firm with a new technology for foiling car thefts. Such cases, according to Mittal, are grounds for great optimism about India's innovation climate.

Lan Xue of Tsinghua University claimed that over the past 10-12 years, China has established the infrastructure necessary for sustained, technology-based growth. The challenge for China is to make the infrastructure work successfully with industry. Other challenges include a wider distribution of benefits from technology and harnessing science and technology to support efforts to address China's enormous environmental problems.

Adam Segal from the Council on Foreign Relations posed the question, "What differentiates young innovators in China?" The first wave, including Lenovo, used a model of getting into new market space. The second generation of innovators is tapping global networks for a confluence of government funding and returning expatriate talent. State-run enterprises do not have this synergy.

Richard Forcier of Hewlett-Packard noted a disparity between China's and India's energy infrastructure. China is pursuing a huge growth in power generation, planning to build 500 coal-fired power plants in the next decade, at the rate of almost one a week, while India's power sector is slowing. Companies in China are building more innovation capacity to attract more experienced managers.

To grow R&D capacity in China, Xue observed that research universities are seeking to work with multinational companies. A key feature of the Indian landscape, Mittal noted, is the growth of public technology incubators, a network of centers where enterprises can tap technical and managerial expertise in a single location. The National Science and Technology Entrepreneurship Development Board (NSTEDB), a division of the Department of Science and Technology, is spearheading the creation of incubators in universities and other institutions. Activities are ramping up, but not all entrepreneurs are taking advantage of their services. Nevertheless, the panel agreed that both countries are doing a great deal to stimulate innovation from the supply side.

In both cases a critical driver of innovation is the country's diaspora, linking the research and commercial enterprise to the global system. Even remotely, Chinese and Indian researchers and business entrepreneurs living abroad provide sources of investment and opportunities for market development. But increasingly, members of the diasporas are returning home to lead research institutions and enterprises, and they bring with them needed managerial expertise as well as links to foreign laboratories and firms with superior capabilities. Equally important, according to Lan Xue, is the role of foreign direct investment in fostering knowledge spillovers, not only to local firms but also to research institutions, including universities, with which the multinationals are forging more and more links.

Foreign influences are helping in both countries to create a culture of creativity, but progress is not necessarily rapid. Hewlett Packard's Forcier remarked that he is impressed by the talent and energy of the local Indian workforce but finds many reluctant to take a great deal of initiative. Mentoring the local staff often involves encouraging employees to raise new ideas in corporate planning processes and not hold back. Lan Xue agreed that in China the tendency is to duplicate previous innovation successes rather than create new products. There are, for example, ten to fifteen Chinese versions of MySpace and Facebook.

Simon questioned the panel about the distribution of innovation-related investment among regions in China and India. Are significant investments being made outside Shanghai and Bangalore? Panel members agreed that there is wide variation in both countries, with some areas showing considerable interest and others relatively little. In India, according to Mittal, most activity remains in the regional hubs, but it is starting to trickle beyond those cities, in directions determined by investment and market contacts. In China, government incentives have led to greater activity in certain western provinces such as Xian, but a large majority of the R&D investment is still concentrated on the East Coast. Less well developed regions tend to follow the central government's lead on innovation policy and to depend on central government resources. Wealthier provinces like Hangzhou, on the other hand, have taken the lead on innovation without depending on national initiatives.

Finally, Simon probed the public-private sector distribution of R&D. Lan Xue observed that in China there has been a dramatic shift in R&D performance in recent years. In 2006, more than 70 percent of research funds were spent by industry, whereas 20 years ago public research institutions accounted for almost that proportion, about 60 percent. On the other hand, multinational corporations account for a large share of the growth – over 70 percent of industrial R&D spending in Shanghai and roughly 30 percent nationwide. Indigenous enterprises also lag in taking advantage of the strengthening of intellectual property rights in recent years. India has yet to achieve a distribution of R&D activity between public and private sectors comparable to that of other industrial countries.

6
The Legal Environment: Competition Policy, Standards, and Intellectual Property

A country that aspires to become a leader in innovation not only must have a well-developed research and commercialization infrastructure and ready availability of investment capital but also must create a legal environment that is conducive to innovation. As STEP board member and session moderator Alan Wm. Wolff noted in his opening remarks, competition policy, standards, and intellectual policy are among the policy levers that countries use to influence innovation. Microsoft or Intel or a biotechnology firm may choose to invest anywhere in the world; but wherever they go, they will be governed by local rules of intellectual property protection and competition policy and technical standards that are likely to reflect local conditions even if they adhere to international standards. The key question for any policy, he said, is whether it promotes innovation. "The impact of these policies can be very positive. They can also be distinctly negative."

The speakers in Session 6 examined some aspects of competition, standards, and the legal environments in China and India in the context of their contribution to innovation and treatment of foreign direct investment in the two countries.

COMPETITION POLICY IN CHINA

Following his introductory remarks, Alan Wolff discussed recent developments in China's competition policy—in particular the newly enacted anti-monopoly law (AML), drafted in a relatively open process, allowing foreign firm participation. Foreign direct investment has been essential to China's development and growth, but now the government of China seeks an "objective symbiosis" between international investment and indigenous innovation. This will entail stronger intellectual property rights and stronger, more vigorously enforced anti-trust laws. Under the new law, a key determinant of market dominance is whether a company has 50 percent of the market. Abuse of such a dominant position can involve sustaining unfairly high prices or refusing to trade with related parties without justification.

In the discussions leading up to the new AML, observers became concerned about how the law will apply to multinational firms and whether it will be used to restrict them unfairly relative to domestic firms. For example, industries dominated by state-owned enterprises are exempt from the law's application altogether.

STANDARD SETTING IN CHINA

Pete Suttmeier of the University of Oregon has studied the use of technical standards as a policy tool of China's government. There is a popular proverb: "Third-class companies make products; second-class companies develop technologies; and first-class companies set the standards." Fifty percent of China's current product standards are based on international standards, but China aspires to internationalize more Chinese standards. The development of Chinese standards is viewed as a means of gaining leverage in international commerce that has been beyond China's reach.

China is wary of the international standards setting process as a result of its experience with Wired Authentication and Privacy Infrastructure (WAPI), DVD technology, and video compression. Its proposed WAPI standard was rejected internationally in March 2006. China's strategy on standards so far has had disappointing results. Still, many Chinese believe that the country has not only a world class capacity for technological innovation but also enormous market power for influencing technical standards and that the two should be developed and exploited hand in hand. The current long-term plan (2006-2020) calls for moving the economy from "Made in China" to "Created in China." In the meantime, against an international background of institutional fluidity, China has pushed for open standards and open source development.

Chinese standards have generally not been successful in first-tier markets, but may fare better in the relatively near term in second- and third-tier markets. In Suttmeier's view, the United States and other advanced countries should engage with China and anticipate a broader "regime insurgency" against the role of the World Trade Organization and other multilateral bodies in setting the rules.

PATENTS AND INNOVATION IN INDIA

Shamnad Basheer, visiting George Washington University law professor, spoke on the evolution of the Indian patent system, which has been driven by the pharmaceutical industry, the dominant patent filing sector (Figure 9). As recently as the 1970 Patent Act, India departed from international norms advocated by the United States in replacing product patents with process patents for pharmaceuticals. When firms understood they could then legally make existing products simply by changing the production process, huge growth followed for the Indian generic manufacturers. Ranbaxy's production of Cefaclor, an antibiotic, is an example of a commercially successful Indian product based on that strategy.

By accepting the 1994 Agreement on Trade-Related Aspects of Intellectual Property (TRIPS) as part of the Uruguay Round trade negotiations, India was obliged to reintroduce pharmaceutical product patents, over huge resistance, and finally did so in the Patent Act of 2005. How does the

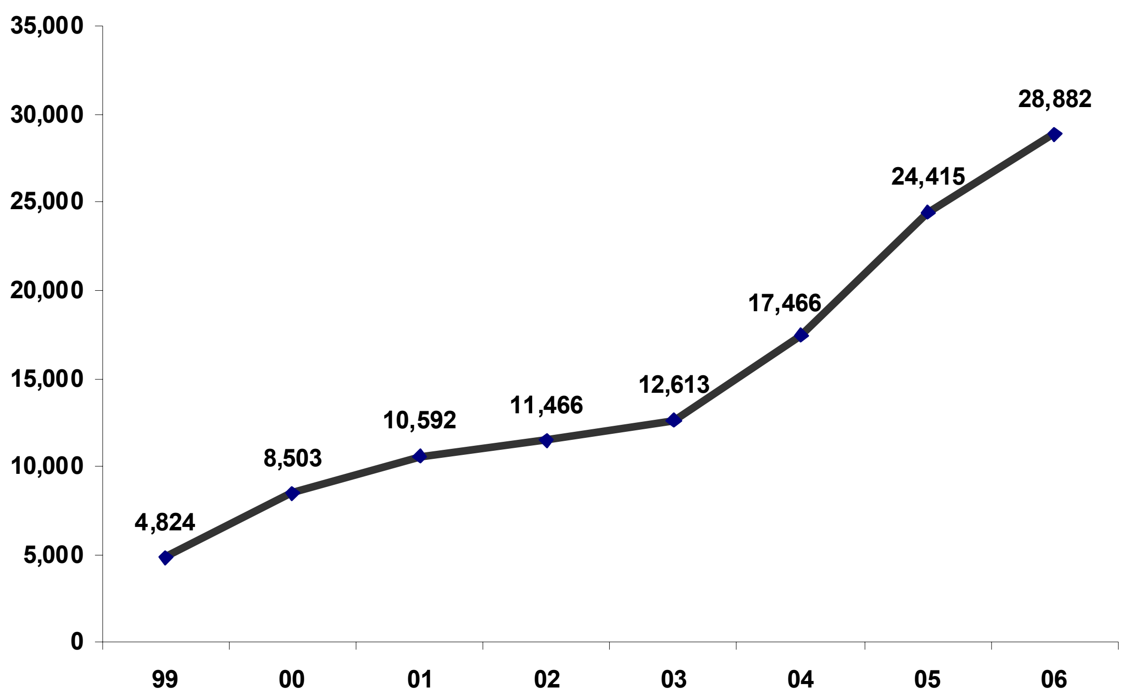

FIGURE 9 Patent applications in India. SOURCE: Basheer

2005 law change business strategies? In particular, does it mean Indian firms will develop more R&D-based innovative products? The answers are not yet clear, in part because of the slowness of the Indian Patent Office, which has only 135 examiners to handle 26,000 patent applications a year and the many post-grant challenges that the system allows. A modernization initiative is now attempting to reduce the time to patent, but it will be slow-going for some time to come.

Bhaven Sampat of Columbia University gave an overview of the top patent applicants in India by volume. They are dominated by multinational pharmaceutical, information technology, and telecommunications firms. Bayer, Pfizer, Honda, Qualcomm, Novartis, Glaxo SmithKline, Microsoft, Samsung, Johnson & Johnson, Merck and Ericsson are among the top 20 patenting entities. Many of their applications are defensive, designed to protect existing products. Indian patent law matters primarily in sectors where the Indian market is gaining a significant share of the global market. IT firms, for example, are not filing many patent applications in India.

THE CHINESE PATENT SYSTEM

Soonhee Jang, an Eli Lilly and Company corporate intellectual property attorney, provided an overview of Chinese patent law. (In 2006, Lilly was among the top multinational pharmaceutical companies in China, with more than 1,000 employees in over 50 cities.) Jang pointed out that China has a civil law system, in contrast to the common law system of the United States. Common law systems derive general rules from specific cases, while civil law systems usually start with an abstract rule that judges interpret and apply in specific cases.

Chinese intellectual property law has evolved repeatedly since 1985, when no patent law existed. The 1985 Act was amended in 1992 and again in 2000, in anticipation of China's entry into the World Trade Organization. In 2006, a third set of amendments was adopted. Meanwhile the State Intellectual Patent Office (SIPO) has grown quickly in numbers and sophistication. In 2006 alone over 500 new examiners were hired, and cumulatively over 1.7 million patents have been granted. Enforcement will and capacity have developed more slowly.

Chinese law provides for three categories of patents—invention patents (affording protection for 20 years), utility model patents (10 years), and design patents (10 years). The latter two types of patents can be obtained more readily than an invention patent, usually in a matter of months (Table 2). Applicants generally seek both a utility and an invention patent at the same time, acquiring the protection of a utility patent relatively quickly and than abandoning it when the longer-term invention patent issues. Patentability criteria include novelty, inventiveness and practical applicability. Unlike the United States there is no provision for term extension for patents on regulated pharmaceuticals, as authorities want generic products to appear in the market as quickly as possible.

TABLE 2 Categories of Patents under Chinese Law

	Invention	**Utility Model**	**Design**
Subject Matter	Any new technical solution relating to a product, a process, or improvement thereof	Any new technical solution relating to the shape, the structure or combination of a product	New design of the shape, the pattern or their combination, or the combination of the color with the shape or pattern of a product
Patent Term (years)	20	10	10
Examination	Substantive Examination	Formality Only	Formality Only
Pendency	22 months	9 months	6 months

SOURCE: Jang

Compensation schemes for rewarding inventors vary and what constitutes reasonable remuneration is sometimes controversial, although a common basis is 2 percent of a firm's after-tax profits on an invention. It seems unlikely that uncertainty about employee compensation is a deterrent to inventiveness and innovation. Between 2000 and 2006, patent applications have increased more than 20 percent every year; filings by Chinese nationals are outpacing those of foreign-owned firms (Figure 10). The top international filers are Japanese, United States, South Korean, and German nationals in that order.

In discussion, the experts on the Chinese and Indian patent systems agreed that it is premature to judge whether the current patent regimes in both countries are providing an impetus to innovative activity. On the other hand, foreign direct investors are voting on the newly strengthened patent systems "with their feet," investing heavily in both China and India.

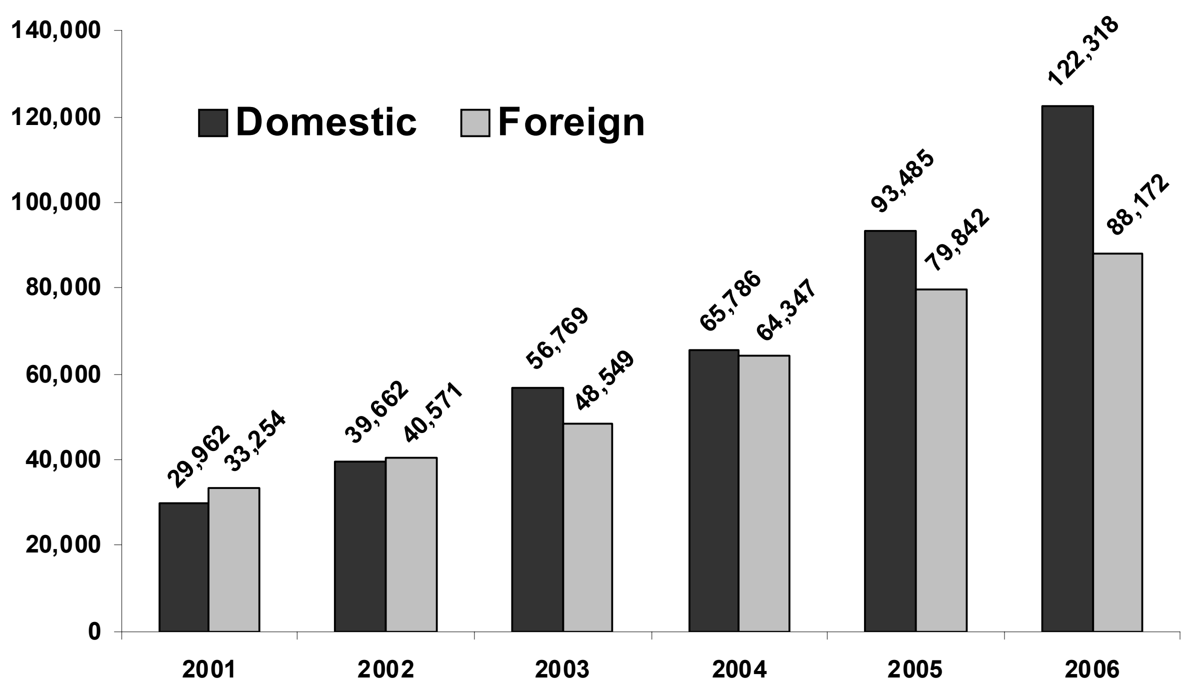

FIGURE 10 Invention patent application filing in China, 2001-2006. SOURCE: Jang

7
Multinationals' Experience

STEP board member Mary Good of the University of Arkansas at Little Rock welcomed participants to the second day of the conference with some observations on the speed of the changes taking place in Asia. Between 1985, when she worked in India as vice president of technology at Allied Signal, and her return there in 1994 as a government official, spectacular changes had occurred which could not have been predicted. Business and governments often have different perspectives on conditions that promote innovation; but one point on which they can agree, and in Asia acted aggressively, is that competition and innovation create paths for prosperity.

Bruce Stokes of the *National Journal*, who served as the moderator of the first session on multinational companies (MNCs), posed a perennial question: where do MNCs' interests and nation states' interests converge and where do they diverge? Is foreign investment in China and India producing results or is it still a bet on the future? Many variables can affect the answers to those questions, but ultimately the perceived self-interests of global firms will play a major role in determining the success of China's and India's efforts to develop their economies' innovation capacity.

INTEL'S PERSPECTIVE

James Jarrett, director of global public policy for Intel Corporation and former president of Intel China, Ltd., observed that 80 percent of the firm's global sales are outside the United States, with 60 percent in Asia. In 2006 the Asian market represented $35.4 billion in sales. Moreover, while conducting R&D in 64 labs worldwide, Intel entered China and India relatively early, in 1985 and 1988, respectively. The scale of R&D operations, however, is vastly different. The company's investment in China ($4 billion) dwarfs its investment in India ($700 million). In terms of market share, China will have 34 percent of Intel's global market in 2008 while India's share will be 11.8 percent. In short, said Jarrett, "In our business you must get China right."

Intel's Shanghai software laboratory, established in 1994, continues to adapt Intel designs to China's demands. The Bangalore Intel laboratory works on advanced semiconductor prototypes such as the tera-scale prototype wafer. The company's needs for middle managers continue to be filled by U.S. nationals for the most part, but Intel is contributing to the pipeline of local technical talent by

- training schoolteachers in 40-hour courses and using computers with 1.6 million K-12 teachers;
- building active relationships with more than 100 research universities; and
- producing textbooks such as *Multi-Core Programming* to help build a capability capacity for leading-edge processes.

Jarrett reiterated the point made earlier that another source of talent for trans-Pacific countries is their diasporas, which are being engaged at a distance but also lured home in greater number. "I think you'll see more and more of that in the future," Jarrett said.

Intel's experience in China exhibits one multinational company's responsiveness to government investment inducements. The company's chip manufacturing operation is its largest in Asia, and the firm recently broke ground on a large-scale wafer fabrication facility in Dalian that will use 90-mm technology and begin operations in 2010. Manufacturing in India had been hampered by infrastructural limitations of power supply and an "awkward" incentive structure but now is moving forward.

Asked about key factors in Intel's decision to locate a major new facility in less-developed Dalian, Jarrett said that the Chinese government had made a decision to diversify industrial growth away from its traditional areas of concentration by a policy combining the restrictions on new facilities in older areas and "world-class" incentives for locating in less developed ones.

CHINA'S EXPERIENCE WITH MULTINATIONAL CORPORATIONS

Jin Chen of Zhejiang University described how MNCs create links between China and international capital networks. At the end of 2004, foreign direct investment (FDI) in China stood at $562 billion. With the Chinese government positioning itself as a "learning government," the level of FDI has risen quickly. Scale expansion and R&D growth have been rapid. From 200 R&D centers in 2001 the number more than quadrupled in five years, to 980 centers. MNC operations are still concentrated in Beijing (primarily in IT), Shanghai (chemical, auto and pharmaceuticals), and Shenzhen (telecom), with a second tier in Guangzhou and other cities.

MNC research in China is largely focused on adaptive R&D, with less devoted to basic research. MNCs, according to Chen, are perceived in China to have both positive and negative effects on indigenous technology development. They contribute to broadening and deepening the overall level of technology. But they can establish strong monopolies on certain closely held technologies that crowd out R&D in Chinese firms, and siphon off top talent that might otherwise be available to domestic firms.

Chen expressed his ambivalence about the fact that seven of his eight recent top graduate students were hired by multinationals. Overall, in Chen's personal judgment, "MNCs have limited positive effects." Yet movement toward a more collaborative innovation paradigm can shift the balance from a modestly positive to a substantially positive contribution to domestic technological capacity. If MNCs were to deepen their collaboration with local firms, then both the firms and China would benefit.

DISCUSSION

In the discussion session, Gail Pesyna of the Alfred P. Sloan Foundation sought clarification of China's and India's investment incentive policies. Jarrett replied that in India they take the form of cash grants and tax incentives. Chen noted that last year China adopted a new scheme, called "Innovation-oriented Country by 2020," which includes 60 measures for promoting R&D, including facility set-up, tax incentives and infrastructural investments. Jarrett added that these policies have a new social value emphasis and indigenous development focus. For example, VC investment incentives are geared to domestic markets rather than the global market.

Addressing the balance between proprietary and more open, collaborative work, Jarrett said that the company's strategy varies from country to country depending on the distribution of technological capability, the host's intellectual property regime, government requirements, and other factors. In China, Intel is actively pursuing collaborations. An example is its work with Tsinghua University to develop a compiler. In India, on the other hand, "we are doing some very proprietary work." Jarrett observed that spillover benefits are as much a function of the movement of human capital as of the open or closed nature of corporate research projects. As in the United States, in both China and India there is considerable turnover in information technology fields, with skilled employees leaving to create startups in software and computing. Intel views this not as a loss for the company but rather a natural phenomenon that contributes to ferment in the field.

8
Simultaneous Sessions

The second session was organized into four breakout sessions, each with presentations and discussions describing the development of Chinese and Indian innovation capacity in a broad sector of the economy or set of related industries – information technology and communications, transport equipment (automobiles and aircraft), pharmaceuticals and biotechnology, and energy. The sessions were intended to highlight and compare key microeconomic trends rather than thoroughly analyze each sector.

INFORMATION TECHNOLOGY AND COMMUNICATIONS

At the outset of the IT session, Ashish Arora of Carnegie Mellon University made two main points about the global software sector. First, the United States still dominates the software industry in a unique way; second, South Korea, Israel, and Japan represent a group of comparably sized second tier producers. In his view, the main story is the "utter dominance" by the United States, with Israel leading the group of "underdog" countries. The United States continues to hold this dominance because it is home to a key population of highly sophisticated software users (Table 3).

In China, 90 percent of total software sales are to the domestic market, a market pulled along by the country's economic boom rather than leading it. Nevertheless, the technological competence among Chinese firms probably exceeds that of Indian firms. Indian firms are moving into higher value-added software development, Arora said, but not necessarily advancing technology. "Human capital is the key," he emphasized (Table 4).

Roy Singham of ThoughtWorks, Inc., had a different perspective on the shifting locus of IT innovation. "We're at the beginning of a 150-year shift in power to Asia." The shift will not be drastic, he speculated. The European Union will remain a significant part of the picture for some time, as will Brazil and Argentina. Still, he suggested, a new "tricycle of innovation" will hinge on the centers of Stockholm, Beijing, and Bangalore.

The emphasis on human capital and value for social capital, Singham said, explains Scandinavia's lead in global IT competitiveness per capita. A value on collaboration, not just competitiveness, can spur global innovation. In this new environment, agility of innovation and fast solutions for new business models will command a premium. He posited that there are two revolutions taking place--one on the process side of enterprise and a second on the product side. In terms of process, he expects to see a less hierarchical approach than he observed on a recent tour of Indian software companies, which reflected the assembly line model from the industrial revolution. Arora responded that the factory model remains workable in how it addresses the high turnover of employees and ensures a company can consistently deliver its product. Is the factory approach a cause of staff turnover or an effect of it? Singham replied that ThoughtWorks has a low 5 percent attrition rate among its staff in India, in large part because it values its employees.

A generation ago the Asian diaspora tended to settle in the United States and elsewhere overseas, but now they are likely to return to their home countries. That change will have a profound effect, according to Singham, who questioned, "How did the United States, which was home of open intellectual debate, lose that advantage?"

TABLE 3 The International SW Industry (2002)

Countries	Sales ($B)	Empl ('000)	Sales/Empl	Sales/GDP
Brazil *	7.7	160 **	45.5 **	1.50%
China	13.3	190 **	37.6	1.1
India	12.5	250	50	2.5
Ireland (MNE)	12.3	15.3	803.9	11
Ireland (Dom)	1.6	12.6	127	1.3
Israel *	4.1	15	273.3	3.7
US	200	1024	195.3	2
Japan **	85	534	159.2	2
Germany *	39.8	300	132.7	2.2
Argentina **	1.35	15	89.3	0.5

SOURCE: Adapted from Arora, A. & Alfonso Gambardella, 2005. "The Globalization of the Software Industry: Perspectives and Opportunities for Developed and Developing Countries," in: Innovation Policy and the Economy, Volume 5, pages 1-32 National Bureau of Economic Research, Inc. *=2001; **=2000

TABLE 4 The Software (SW) Industry in India ($B USD)

	FY 2004	FY 2005	FY 2006	FY 2007
IT Services	**10.4**	**13.5**	**17.8**	**23.5**
-Exports	7.3	10.0	13.3	18.0
-Domestic	3.1	3.5	4.5	5.5
ITES-BPO	**3.4**	**5.2**	**7.2**	**9.5**
-Exports	3.1	4.6	6.3	8.4
-Domestic	0.3	0.6	0.9	1.1
Eng, R&D Serv and Products	**2.9**	**3.9**	**5.3**	**6.5**
-Exports	2.5	3.1	4.0	4.9
-Domestic	0.4	0.8	1.3	1.6
Total Software and Services Revenues	**16.7**	**22.6**	**30.3**	**39.5**
SW Exports	**12.9**	**17.7**	**23.6**	**31.3**
Hardware	**5.0**	**5.9**	**7.0**	**8.5**
Total IT Industry (including Hardware)	**21.6**	**28.4**	**37.4**	**48.0**

SOURCE: Adapted from Indian IT-BPO Industry Factsheet (2008) NASSCOM

Frictions in labor markets are different from the frictions that exist within capital markets. Singham posited that talent is less transportable than capital—a point that was debated. Arora maintained that capital and talent can both move; the sticky part, in his opinion, is proximity to users.

Jason Dedrick of the University of California, Irvine, spoke on IT market opportunities in China and India (Table 5). He amplified a theme noted by others—innovation is most intense in sectors where users are nearby. This means that the greatest potential for innovation exists in sectors where Chinese and Indian markets are growing rapidly. By 2006 there were 415 million cell phone users in China, compared to 15 million in India. Personal computer shipments that year to China were 28 million; to India, 7.7 million. In understanding these markets we will see where different products are likely to emerge. Multinational corporations are struggling with this shift, while it creates opportunities for local firms in both countries.

By building on their domestic market base, local firms can launch into the global market, as Haier and Huawei in China have done. The Chinese government's strategy of developing domestic technology and dictating standards may be a miscalculation, insofar as it is hard for any firm to keep teams moving ahead on both the domestic standard and the international format.

Table 5 Emerging Market Opportunities

	China	India
Installed PC base, 2005	54 million	15 M
PC shipments, 2006	28 M	7.5 M
Domestic software market	$3.9 B	$1.4 B
Domestic IT services market	$6.2 B	$3.7 B
Cell phones in use, 2006	415 M	150 M
Cell phone shipments, 2006	130 M	75 M*

SOURCE: Dedrick, *new subscribers

Indian firms are gaining in scale and scope, with implications for U.S. enterprise. One implication for U.S. workers is that there will be greater needs for project management, cross-technology skills, business and industry knowledge, as well as cross-cultural management. Dedrick characterized this as a need for "T-shaped people," with the vertical base of the T representing technical depth and the top horizontal bar representing broad management familiarity.

Balaji Yallavalli of Infosys Technologies, Ltd., illustrated how the "world is flattening" by describing his own situation—managing a company based in India, working from Plano, Texas, and New York. The structural shift in demographics is strengthening the position of developing countries. At the same time, technological applications are "being pushed out of companies" and into the hands of their customers, in various ways ranging from air passengers who print their own boarding passes, to greater user involvement in software development. His observations about shifts in the dominant modes of thinking resonated with other participants in the IT session. Technology can help predict the future turns in a sector and identify ways to weather those changes. Yallavalli described Infosys as "a company that can scale ideas quickly," not an R&D-based company, but one based on innovation to meet business model needs. He cited a recent news article suggesting that outsourcing was sufficiently successful that India was now exporting jobs abroad.

Yallavalli reiterated that with time-to-market shrinking for innovations and with customers wanting to be part of value creation, it is not as necessary to climb the technological ladder as it is to move toward customer satisfaction and the value chain. "Innovation is the only means to sustain customer loyalty in a flattening world," he said.

Lee Ting of of Lenovo observed, "True innovation occurs [mainly] at headquarters." In Lenovo's case, they aimed to keep innovation hubs intact in a larger system. For example, the ThinkPad design process is still driven from its former IBM base in Raleigh, North Carolina, although Lenovo is based in Taiwan. Domestic firms in China are well situated to innovate for the domestic market and get ahead of MNCs. PayPal, for example, shut down its Chinese operation because it did not adapt to the Chinese payment preferences. There is not only a need for innovation based on technology but also for innovative new business models.

Patrick Canavan of Motorola, the session moderator, told how in Motorola's experience the company's innovation in China came, in one instance, from a disappointed company executive who engaged local technical expertise to find a market sensitive solution. Cycles of staff departures among competitors affect the dynamics of innovation.

On the question of whether formal education would play a large role in the shift ahead, Singham noted that 10 percent of ThoughtWorks employees do not have bachelor's degrees, just as some leaders of the U.S. software industry lack them. "Software is a weird world," he said, where innovation is correlated more with creativity than with education. Creativity is more crucial in designing new software than in engineering a new hardware chip, for example, and is the quality on which ThoughtWorks places a premium. Singham insisted that the company has a global cap on the number of engineers it hires. "We believe they stifle creativity," he said provocatively.

Alongside growing creativity, there is a growing acceptance of risk in China and India, linked to their demographic changes. There are also structural differences in risk-taking in different societies. Bankruptcy in Japan, for example, can spell disaster; in Silicon Valley it is far easier to recover from bankruptcy. The latter encourages innovators.

Asked about what activities may shift to Asia, the panel made several suggestions. State-owned enterprises and their international partnerships will shift the dynamic, Canavan noted. For example, China Mobile's stake in the Pakistan market and China's investment in Africa would help China grow its influence in the global market. Others felt the shift would depend less on government policies and more on technological innovation coming out of Indian firms and business-model innovations in China. By 2020, one predicted, India's largest firms will be capitalizing on the domestic market there.

Martin Kenney pursued the question of different types of creativity, in particular at Infosys. Yallavalli acknowledged tensions between fostering an open and creative environment on the company campus and the expectations of stakeholders to find a serious, no-nonsense approach. Among their clients, he noted a kind of double standard; they want employees to be creative but not at the expense of the existing corporate structure.

TRANSPORT EQUIPMENT

This session focused primarily on cars, trucks, and civilian and military aircraft as these are expected to be areas of major domestic market growth and manufacturing capacity expansion in both China and India.

In the part of the session devoted to aviation, Thomas Pickering from Boeing discussed that company's operations and plans in both India and China. In particular he noted that the opening of Indian defense procurement will mean greater opportunities in that country for western companies such as Boeing and Martin Marietta. It promised to become a major market.

Rishikesha Krishnan of the Indian Institute of Management in Bangalore reported that the Indian government is thinking about what it will take to move from its current engineering design capabilities in aviation and aerospace to the development of a domestic production capacity in those areas. Such a production capacity is largely nonexistent in India at the moment, but the government aspires to develop one.

Warren Harris, the chief executive officer of the design services firm INCAT, offered the complementary observation that the automotive and aerospace industries are moving from outsourcing to globalizing innovation. That is, where innovation in these industries has been limited mostly to companies in the developed countries, it is now being spread much more broadly around the globe. Access to qualified personnel is a key driver in this globalization of innovation, he said.

A principal theme of the session was the growing sophistication of engineering services in India and China. "If anyone has the notion that the variety and types of engineering services being outsourced to India are at the lower end of the value-added chain, they are seriously out of date," according to Pete Engardio, *BusinessWeek* senior writer, who described some of the design work he observed on recent visits to a number of service firms in India. Companies there are working on a variety of sophisticated projects in the aviation and automotive sectors, he said, from fuselage design and avionics to passenger car platforms, and this work is being done in India not only by the multinationals but also by Indian-owned and domestically headquartered companies.

This development, in Engardio's view, is a function of the disintegration of vertical integration in global manufacturing, the emphasis on modular production and much shorter production cycles, the importance of embedded software in many products, and the effects of various government policies, such as those that require a significant domestic contribution in manufactured items. The movement of design services to places like India and China has in large part been a function of cost, he said, but increasingly it is also being done in pursuit of talent. In short-run economic terms, the most important topic discussed in the session was the rapid growth of both the Chinese and Indian markets for passenger vehicles and the efforts of domestic producers in both countries to ensure that they have the capacity to meet that demand.

Paul McCarthy, PriceWaterhouseCoopers consultant on the automotive industries in both

India and China, gave an overview of market trends in both countries. Between 2006 and 2011, China's production is projected to increase by nearly 50 percent, while India's production is expected to jump by nearly 110 percent in the same period. Although Chinese production capacity is still more than three times as large as India's—7 million versus just over 2 million vehicles per year – expansion is occurring at comparable rates.

McCarthy characterized innovation in the two industries in different dimensions. One pattern is domestic companies' adoption of Western and Japanese innovations by copying, licensing, or entering into joint ventures. He illustrated Chinese and Indian innovation, in its most primitive form, with a series photographs of pairs of vehicles—for example, a 2007 pickup truck made by the Chinese company Chamco and a 2004 Toyota Tundra. They appeared nearly identical.

Purchasing rights to designs and components, on the other hand, offers an opportunity for learning by domestic companies as well as business opportunities for foreign intellectual property holders. There are a number of examples, including Cummins' licensing of its diesel engine technology to Dongfeng of China and Tata of India.

Multinationals' R&D activity in China or India constitutes a second type of innovation common to other industries. "Every major multinational automaker has at least one research facility in either India or China," McCarthy observed, the result as in other cases of lower costs and skilled labor availability.

The third category consists of local companies developing innovations independent of MNCs. One example is Tata's recently announced development of an extremely low-cost automobile for mass markets with wide income disparities. This may drive a low-cost automobile revolution among international as well as Chinese and Indian manufacturers.

Other session participants focused primarily on the development of the Chinese passenger automobile market, which Zheng Jane Zhao of the University of Kansas Business School projected will continue to grow at the current robust rate for about 15 more years, becoming a huge factor in the global market. Every major multinational car manufacturer has a presence in China, Zhao said, but these companies mainly conduct only component innovation in China and keep their architectural innovation at home. It is the architectural innovation—changing the overall layout of the vehicle, including power train development—that is the core competency of automakers, and the multinationals generally try to protect their core competencies by doing this architectural innovation at home.

In the past, multinationals have accounted for almost all the cars sold in China, McCarthy noted, but that is rapidly changing. In 2007, cars made by domestic manufacturers accounted for an estimated 32 percent of the domestic car market, up from just 11 percent in 2004. The Chinese auto makers are competing on the low end, and, as a result, are far less profitable than the multinational auto makers selling cars in China. Furthermore, the R&D expenditures of Chinese automotive companies are still very low compared to producers in developed countries—0.63 percent versus 3 to 5 percent in western companies. "Even though we are seeing more and more market and design innovation, technical innovation still remains weak," McCarthy said. "Chinese companies need to develop their R&D capability in core technologies, such as engine, transmission, and chassis."

The Chinese government is encouraging the automotive industry to develop its own indigenous innovation, and China's 11th Five-Year Plan explicitly singles out automotive innovation and development for advancement. The government's objectives outlined in the plan include upgrading local R&D capabilities, creating more environmentally friendly and energy-efficient vehicles, building indigenous brands, and speeding up industry consolidation. As for prospects that Chinese manufacturers will become major suppliers in other markets, the development of brand identification is perhaps even more critical than technological innovation. Chinese auto makers are handicapped in this regard not only by a history of poor quality but also by characteristics of the domestic market. In particular, brand name recognition has little economic value in China.

Furthermore, Zhao said, the Chinese automotive industry is hampered by its fragmentation, with many smaller companies competing for market share. "Most car makers are not producing at economic scale," she said, "and 121 out of 128 car brands produce less than 0.1 million units each year. There are too many players in each segment, and yet new entrants are still entering." Thus the government is pushing for consolidation, and the MNCs may be helping the process. Volkswagen, for example, has consolidated production planning and purchasing processes between its two Chinese joint venture partners. It is likely that consolidation will be pronounced trend in the industry in the next few years, Zhao suggested.

Over the past decade, Morgenthaler noted, Chinese auto makers have generally relied on alliances with multinationals for much of their innovation, but this is being questioned because the alliances limit the Chinese companies' ability to control their own destiny and brand identity. Thus they are now tending to learn by outsourcing and acquisitions rather than by alliances.

Meanwhile, according to McCarthy, Chinese firms are aspiring to move up the ladder from copier to joint venture partner, to semi- and then fully independent innovator. The best known automaker, Chery, he judged to be somewhere between phase two and phase three, with government-supported ambitions to achieve phase four in the next few years.

PHARMACEUTICALS AND BIOTECHNOLOGY

Charles Cooney of the Massachusetts Institute of Technology, who chaired the breakout session on pharmaceuticals and biotechnology, used the concept of value chain to frame a discussion of the role of China and India in the biopharma sector. A therapeutic product goes through a series of steps in its development—discovery, formulation, clinical trials, regulatory approval, manufacturing, and distribution. Each of those steps may offer opportunities for an emerging economy to participate. Which steps in this value chain are the most likely areas that China and India will make major contributions in the next decade or two?

Recently, Cooney said, a number of multinational pharmaceutical and biotech corporations have been outsourcing work to China and India. This work represents several different points in the value chain. A number of multinationals have R&D efforts in the two countries, for example, and many of them are developing partnerships with indigenous companies, particularly in India, to work on early-stage discovery and other research. There are also a large number of multinationals doing manufacturing in the two countries. India has the largest number of FDA-approved manufacturing facilities outside the United States, while China is somewhat less advanced with respect to best manufacturing practices.

Both countries also serve as the site for much clinical trial work, Cooney said; and quite recently China has surpassed India as the site of the largest number of trials outside of the developed countries. Vincent Ling, vice president of molecular biology at Dragonfly Sciences, documented the shift in locus of clinical trials with Food and Drug Administration data. In 1997, 85 percent of all safety and efficacy clinical drug trials were performed in the United States, 10 percent in Europe, and only 5 percent in the rest of the world. By 2005, the United States accounted for only 66 percent of clinical trials, Europe 13 percent, and the ROW more than 20 percent.

Several factors are driving this offshoring, Cooney said, including the lower cost of building manufacturing facilities in India and China compared with the United States, as well as lower labor costs, although the latter are increasing rapidly. Multinational corporations are also attracted by the large markets in the two countries and, on the clinical side, by the extremely large patient populations.

Intellectual property regimes are another determinant of how the biopharma sector has evolved in China and India, according to Cooney. For example, Indian patent law for many years allowed only pharmaceutical process, not product, patents. As a result, Indian companies have highly developed process technologies and strength in manufacturing and selling generic drugs. In Cooney's opinion, Indian and Chinese companies will soon dominate the generic sector.

Ling described the corporate experience of Dragonfly Sciences in performing a range of specialized and customized activities. Dragonfly performs discovery biology, serves as an overflow laboratory for large pharmaceutical companies, and acts as an implementation lab for virtual biotech companies that need research performed. Because of the high cost of these services in the United States, Dragonfly set up its main operations in China, with a small headquarters staff in the United States. Currently, the Shanghai laboratory employs 20 full-time workers while the U.S. headquarters office has three.

The imperative for the pharmaceutical industry, according to Ling, is to manage the escalating cost of drug development, testing and approval and/or increase the success rate in the testing phase. "You have outsourcing simply because the cost has to be managed," he said. "As more small and mid-tier pharmaceutical companies strive to become clinical organizations, the high cost and low success rates of human studies will create significant challenges for that sector and lead them to adopt outsourcing and other clinical practices that big pharma is using to control costs and manage risks."

Speaking of Dragonfly's specific experience in outsourcing to China, Ling summarized a number of advantages and disadvantages. A major advantage is the cost of scientific labor in Shanghai, which is one-fourth to one-seventh the cost in the United States. On the other hand, the Chinese biotechnology industry is very young and most scientists are newly minted Ph.D.s or have less than three years of experience. Chinese bioscientists tend to have good learning skills but most of them perform well below the level of their peers in the United States and Western Europe. U.S.-trained biomedical scientists generally want to remain in the United States to conduct research. Regulation of biomedical research and product development is less onerous in China than in the United States, according to Ling; but it also tends to be more arbitrary and unpredictable. Dragonfly's Shanghai laboratory was set up to comply with U.S. as well as Chinese regulations. Nevertheless, Chinese inspectors often provided little guidance about what was expected. Chinese workers are willing to work hard and comply with instructions, yet they are reluctant to participate in problem-solving discussions or to offer new ideas and opinions.

One of the keys to Dragonfly's outsourcing has been maintaining what Ling called "granularity," where data are regularly communicated from Shanghai to the U.S. office. Because the biological experiments they perform are generally messy and often produce unanticipated results, the experiments need to be overseen by an experienced manager with a constant eye on the data being produced. Furthermore, Dragonfly's MNC clients often lack confidence in the integrity of the research results. They required that the Shanghai workers upload data daily for review by the U.S. staff.

Another disadvantage of working in China is the cost of reagents and the difficulty in getting them quickly. "They may have all the equipment," Ling opined, "but you cannot necessarily get the materials." In spite of these disadvantages and inconveniences, Ling concluded, the lower cost of labor outweighs all other factors. Ling expects this advantage to persist at least for the next decade.

Surprisingly, another part of the value chain that may offer opportunities for innovators in China and India is the discovery of new pharmaceuticals. Kuan Wang from the National Institutes of Health spoke about the possibility of using knowledge from the traditional medicines of China and India to develop new treatments. There have been many success stories involving the traditional herb medicines as sources of drug discovery, Wang said. GL-331 is an anticancer drug in Phase II trials, for example, and PA-334 is in preclinical studies for use as an inhibitor of HIV reverse transcriptase. A more familiar example is curcumin, the active substance in the spice turmeric. Cell and animal studies have indicated that it has anti-tumor, anti-inflammatory, and anti-pain properties and that it may be useful against neurodegenerative diseases such as Alzheimer's. In its natural form its effectiveness is limited because of poor solubility in water and poor bioavailability, but encapsulating it in nanoparticles has been shown to increase its bioavailability, and data suggest that curcumin in this form inhibits pancreatic cancer cell lines.

China has a number of ongoing efforts to push the development of traditional medicine, Wang said, but there are a number of challenges facing that development. Foremost is the lack of western-style placebo-controlled studies establishing the efficacy of these traditional treatments. A great deal of research must be done to explore the clinical pharmacology and pharmacodynamics of these traditional medicines; and studies are needed on how these medicines behave when combined with western medicine, including the possibility of adverse interactions. Intellectual property rights will also be tricky to establish and disputes difficult to resolve. Traditional medicines themselves cannot be patented, but derivatives can be, so research will be needed both to identify the effective ingredients in traditional medicines and to work from those ingredients to discover compounds that can be patented. Finally, there is no large international market for traditional medicine from India and China. Nonetheless, if these challenges can be overcome, traditional medicine can provide a platform from which China and India could become innovators in the pharmaceutical and biotechnology worlds.

ENERGY

The energy session's first speaker, Dilip Ahuja of the National Institute for Advanced Studies in Bangalore, India, described China's and India's role in the link between energy and climate change. Because more than two-thirds of anthropogenic greenhouse gases are energy-related, Ahuja said, the need to reduce carbon emissions from power generation is clear. And because the greatest growth in power demand over the next several decades is projected to come from China and India, innovations in the production, distribution, and use of energy in these two countries will play a major role in determining how well the world responds to the threat of global warming.

On the other hand, many in China and India are skeptical about the motivations of those in the developed countries who tell those in the developing countries that they need to worry more about climate change. There is a suspicion that the arguments for reducing greenhouse gases are really an attempt to slow down growth in China and India as they become serious economic competitors of the United States, Europe, and Japan. A new approach is needed if China and India are to work with the developed countries on climate change.

The first step out of the impasse, according to Ahuja, will be for the developed countries to transform their emissions goals into firm commitments, as articulated by the Global Leadership for Climate Action, which recommended that developed countries should commit to reducing their emissions by 30 percent between 2013 and 2020, while the rapidly industrializing countries, such as India and China, should reduce their energy intensity by a similar amount. Energy intensity is the ratio of a country's energy consumption to its gross domestic product (GDP), so it measures how much energy a country uses to produce a certain economic output.

Reducing energy intensity by this amount in China and India will require a variety of innovations but is feasible, Ahuja said. Over the past several decades, for instance, the average energy intensity of all countries around the world has been declining by 1.25 percent per year. In India, energy intensity has declined by about half over the past 30 years.

Trevor Houser, a director at China Strategic Advisory, discussed Chinese energy use and Chinese energy R&D (Figure 11). He noted that in 1980 the entire Chinese energy sector was controlled by the government; without any profit motive at work, investment was based purely on government plans. Since then much of the energy sector has been turned over to private corporations, resulting in large gains in efficiency. China's energy intensity today is only one-third of what it was in 1978. On the other hand, the private operators of energy companies have no incentives to limit emissions.

The demand for energy in China is increasing at a phenomenal rate, Houser noted. Currently China has about 680 gigawatts of installed generating capacity, much of it added very recently. About 100 gigawatts was brought on line two years ago and another 100 gigawatts

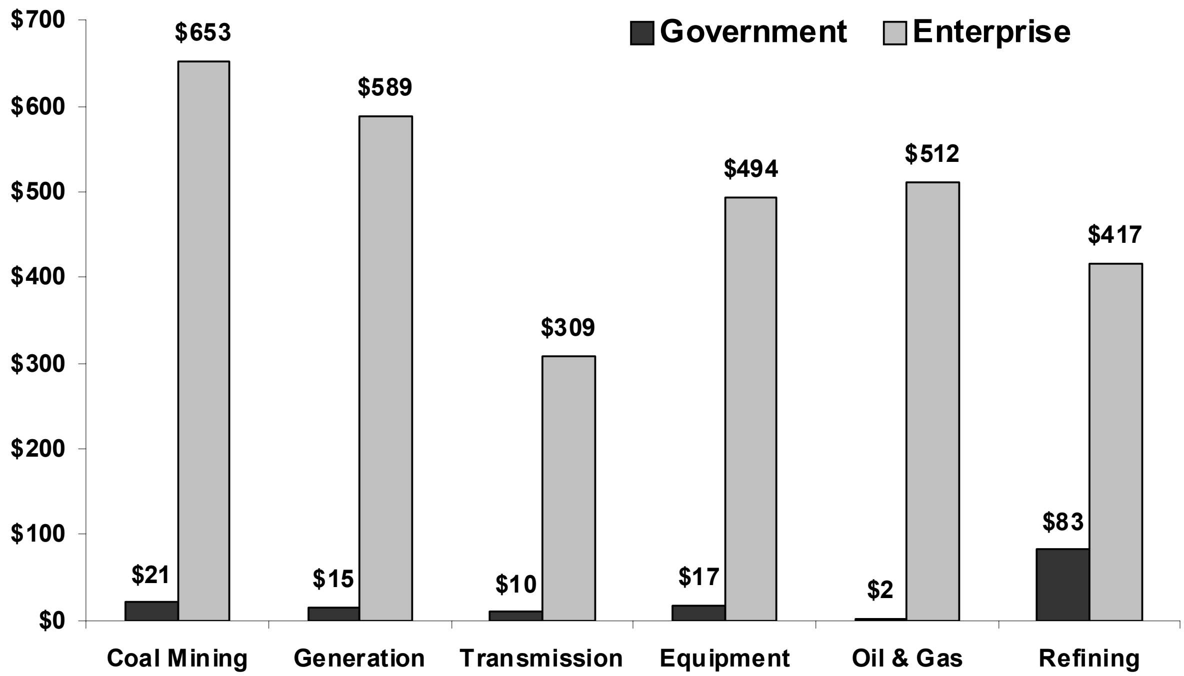

FIGURE 11 Chinese spending on energy R&D ($ millions, 2004) SOURCE: Houser

last year. It is projected that by 2020, China will have installed another 1000 to 1300 gigawatts of capacity. To put that in perspective, the total current generating capacity of the United States is now about 900 gigawatts.

"When you have power demand growing that fast, it creates challenges for innovation because you are trying to throw whatever you have on the grid as quickly as possible," Houser observed. Large-scale blackouts in 2004 and 2005 pushed China to add power as quickly as possible, with very little investment in R&D and reliance instead on the technology most familiar to Chinese energy companies—pulverized coal. The Chinese power industry has become very adept at building coal-fired power plants in a period of shortage, taking about six months from start to finish. Last year, coal accounted for 90 of the 100 gigawatts added by Chinese power producers, with hydro and wind accounting for the remainder.

The future will look very similar, Houser said, although Chinese companies are trying to diversify their power generating capacity somewhat. For example, China will add about 40 gigawatts of nuclear power over the next 15 to 20 years, making the country the largest nuclear power market in the world; but nuclear power will account for only 3 to 4 percent of the total installed capacity in 2020. Initially, the nuclear technology will be supplied by Westinghouse, which will build several nuclear plants and then transfer the technology to local companies that will build that next thirty plants.

Hydroelectric power is the major hope for meeting China's goal of supplying 15 percent of its energy demand with renewable sources by 2020, Houser said. The plan is to have 240 gigawatts of hydro power by then, but that is the equivalent of building a new Three Gorges Dam every two years, which may not be politically feasible. Natural gas will be used to a certain extent in power generation, but it is needed for other purposes, such as feedstock in chemical plants and for household uses. Thus coal will continue to be the source of a large majority of the country's power for the foreseeable future.

Because China will account for so much of the world's new power generation capacity over the next couple of decades, according to Houser, the innovation choices made in China will be crucial not just for that country but also for the rest of the world. He suggested that it is crucially important to get the incentives for cleaner technologies right in China because the country's huge market and position as a global manufacturing base for energy technology. If China builds a large amount of capacity with wind power, for example, world prices for that technology will drop significantly. But the same is true of dirtier technologies such as pulverized coal. Costs will go down, encouraging increased worldwide use.

Lifeng Zhao of Harvard's John F. Kennedy School of Government spoke on prospects for clean coal technologies under development in China. Agreeing with Houser that coal will dominate China's energy needs for the next few decades, she said that as a result, China is focusing a great deal of attention on clean coal technologies.

A number of agencies in China are funding a variety of approaches to clean coal technology, Zhao said. A great deal of attention is being paid to increasing efficiency, for instance, and to various pollution control technologies. New coal-fired plants are being equipped with flue gas desulfurization (FGD) units, and existing plants will need to be retrofitted with the FGD units to meet standards on emissions of sulfur dioxide. New plants are also setting aside space for future flue gas denitrification equipment installations, and emission standards are being prescribed for nitrogen oxides.

The Chinese Ministry of Science and Technology is supporting R&D efforts in a number of coal technologies, including circulation fluidized boiler (CFB) plants, which are high efficiency and low polluting; ultrasupercritical pulverized coal power generation technology, which is also high efficiency but has back-end clean-up to keep emissions at a minimum; integrated gasification combined cycle plants, which can be almost as clean as plants burning natural gas; and coal gasification and liquification technologies. Some of these technologies have already been put to work in China, Zhao said. In April 2005 China opened a 300-megawatt CFB plant made with imported technology and equipment; and in June 2006 it started up a 300-megawatt CFB plant that was made domestically. More than ten other 300-megawatt CFB plants are currently under construction. Other innovative coal technologies being explored in China are direct hydrogen production from coal and simultaneous carbon dioxide control and removal of gaseous pollutants during coal combustion.

Finally, Zhao noted, even though China is going to be heavily dependent on coal for the foreseeable future, there is still room for innovation in other sectors—nuclear, wind, and solar cell technology, among others—and other countries should be thinking of China as a market for innovative technologies in these areas.

9
Concluding Observations

In the final session of the conference, participants sought to identify some of the most important themes that had been identified over the previous day and a half. Moderator Denis Simon of the Levin Institute began the session by suggesting five key points:

- We are entering an era with multiple scenarios, much fluidity and turbulence, and potential for international economic and political conflict.
- China is producing a huge number of science and engineering graduates for what may be different paths of talent -- a "just in case" strategic innovation on the "just in time" business philosophy. Understanding the demand for talent will be important.
- For the United States, China poses a paradigm change far greater than Japan's growth in the 1980s. All the systems that we have taken for granted—manufacturing, education, competition—are unraveling, so Americans need to put on new glasses for viewing the world. One reality is that multinational companies have moved much further into globalization than most people perceive or understand.
- In education, the issue is not quantity of academic degrees but quality of talent. Talent must be prepared to adapt to new environments, understand how to manage risk and uncertainty, and know how to make decisions.
- Does the U.S. government understand what these trends mean? What are the public policy implications? Clearly, there is a need to adapt policy more quickly.

Pete Engardio of *BusinessWeek* observed that the conference had not turned up examples of important next-generation products coming out of China or India. Was that a function of the sectors examined or of looking in the rearview mirror?

According to Marco di Capua of the Beijing office of the U.S. Department of Energy, the fact that the world is entering an energy-constrained era is not sufficiently appreciated in the United States. Important energy issues will be production, structure, diversification and competition, and new sources. A key challenge will be how to extract oil from new or marginal sources without creating huge carbon emissions. Another will be dealing with unpleasant historical legacies. A third is how we innovate in the consumption of energy. The United States can be a leader, not by "beating others" in competition but by showing the way.

Several speakers referred to the importance of labor mobility as a source of cross-pollination in the emerging global economy. In the near term the United States is likely to experience a movement of highly trained people back to their countries of origin, including India and China. But the United States should endeavor to remain a magnet for foreign talent, for example by lowering barriers to entry, including delays in visa processing.

Near the 50th anniversary of the Soviet launch of Sputnik, conference participants were reminded that the prospect of Chinese and Indian competition may spur efforts to renew U.S. education and innovation. But conference chair David Morgenthaler observed that this will depend on recognizing that opportunities and needs change. Strikingly, the United States lacks a business plan for its future. The economy is riding Moore's Law regarding the increase in computer processing power for a few more years; but beyond that, future drivers of growth are unclear. What is clear, he said, is that the United States needs to do a better job of strategic planning as the economies of China and India will surpass ours in size.

Chinese and Indian participants—in particular Mu Rongping of the Chinese Academy and Rishikesha Krishnan of the Indian Institute of Management—noted that there will continue to be points of tension between their countries and the United States, particularly over trade and the U.S. current account deficit; but they expressed confidence in the flexibility of the U.S. economy and its ability to adapt and in the ability of all three countries to learn from each other how to sustain innovation and growth.

Appendix A

THE DRAGON AND THE ELEPHANT

Understanding the Development of Innovation Capacity in China and India

The National Academies
Washington, DC

CONFERENCE AGENDA

Monday, September 24, 2007

8:30 AM ***Welcome and Introductions***
Ralph Cicerone, National Academy of Sciences
David T. Morgenthaler, Morgenthaler Ventures, *Chair*

8:45 AM ***Session 1: India and China in the Global Economy***
David T. Morgenthaler, Morgenthaler Ventures, *Moderator*
Nicholas R. Lardy, Peterson Institute for International Economics
Arvind Panagariya, Columbia University
Sean Dougherty, OECD Economics Department

9:45 AM ***Session II: What is Our Interest?***
Norman Neureiter, AAAS and U.S-Indian S&T Forum, *Moderator*
Tony Hey, Microsoft Research
Kent Hughes, Woodrow Wilson International Center for Scholars
Da Hsuan Feng, University of Texas Dallas

10:45 AM ***Session III: Human Capital Development***
Pete Engardio, *BusinessWeek, Moderator*
V.S. Ramamurthy, Chairman, Indian Institute of Technology
Devesh Kapur, University of Pennsylvania
Vivek Wadhwa, Harvard School of Law Wertheim Fellow
Jai Menon, IBM Corporation
Cong Cao, Levin Graduate Institute, State University of New York

12:00 Noon ***Session IV: Keynote Speech***
Sam Pitroda, Indian Knowledge Commission

1:30 PM ***Session V: Capital Markets and Investment***
David T. Morgenthaler, Morgenthaler Ventures, *Moderator*
Martin F. Kenney, University of California at Davis
Oded Shenkar, Ohio State University
Lee S. Ting, W.R. Hambrecht and Lenovo
Sandra Lawson, Goldman Sachs

3:00 PM ***Session VI: Research and Commercialization Infrastructure***

Introduction:

J. Thomas Ratchford, George Mason University, *Chair*
Mu Rongping, Institute of Policy and Management, Chinese Academy of Sciences

Panel:

Denis F. Simon, Levin Graduate Institute**,** SUNY, *Moderator*
Lan Xue, Tsinghua University, Beijing
Harkesh K. Mittal, Department of Science and Technology, India
Adam Segal, Council on Foreign Relations
Carl Dahlman, Georgetown University
Venkatesh Rao Aiyagari, Science and Engineering Research Council, Department of Science and Technology, India
Richard Forcier, Hewlett-Packard

4:45 PM ***Session VII: Legal Environment: Competition Policy, Standards, and Intellectual Property***

Alan Wm. Wolff, Dewey Ballantine, *Moderator*
Pete Suttmeier, University of Oregon
Shamnad Basheer, George Washington University Law Center
Bhaven Sampat, Columbia University
Soonhee Jang, Eli Lilly

6:00 PM ***Poster Session in the Great Hall***

Tuesday, September 25, 2007

9:00 AM ***Welcome and Introduction***

Mary L. Good, University of Arkansas at Little Rock, *Chair*

9:15 AM ***Session VIII: Multinationals' Experience***

Bruce Stokes, *National Journal, Moderator*
Jim Jarrett, Intel Corp.
Jin Chen, Zhejiang University

10:30 AM ***Session IX: Industry Trends***

Section 1: ITC Products and Services

Patrick Canavan, Motorolla, *Moderator*
Ashish Arora, Carnegie Mellon University
Jason Dedrick, University of California at Irvine
Lee S. Ting, W.R. Hambrecht and Lenovo
Balaji Yellavalli, Infosys Technologies, Ltd.
Roy Singham, ThoughtWorks, Inc.

Section 2: Automobiles and Aerospace Manufacturing

Mary Good, University of Arkansas at Little Rock, *Moderator*
Pete Engardio, *BusinessWeek*
Thomas Pickering, Boeing
Paul T. McCarthy, PricewaterhouseCoopers LLP

Jane Zhao, University of Kansas School of Business
Warren Harris, Incat, a Tata Technologies Company
Rishikesha T. Krishnan, Indian Institute of Management Bangalore

Section 3: Pharmaceuticals and Biotechnology
Charles L. Cooney, Massachusetts Institute of Technology, *Moderator*
Vincent Ling, Dragonfly Sciences, Inc.
Kuan Wang, National Institutes of Health

Section 4: Energy
Marco Di Capua, U.S. Department of Energy/Beijing, *Moderator*
Dilip R. Ahuja, National Institute of Advanced Studies, India
Trevor Houser, China Strategic Advisory
Lifeng Zhao, John F. Kennedy School of Government, Harvard University

1:30 PM Plenary ***Session X: Reports from Breakout Sessions***

2:45 PM ***Session XI: What Did We Learn?***
Denis F. Simon, SUNY Levin Graduate Institute
Marco Di Capua, U.S. Department of Energy
Pete Engardio, *BusinessWeek*
Mu Rongping, Chinese Academy of Sciences
Rishikesha Krishnan, Indian Institute of Management

3:30 PM ***Adjourn***

Appendix B

CONFERENCE POSTER SESSION PRESENTERS

Survey of the Human Resource Development Process in India: Policy and Incentives
Pritam Banerjee
George Mason University

Fostering Indo-Swiss Partnerships: An Early Report on the Swiss Main Project
Myrna Flores
University of Applied Sciences – Switzerland

Small Software Firms in India: Innovators or Just Survivors?
P. Vigneswara Ilavarasan
Indian Institute of Technology, Delhi

Basic Biomedical Research in China and India
Kathryn Miller-Jensen
University of California at Berkeley

Assessing the Emergence of China, Singapore, and India in Human Embryonic Stem Cell Science
Aaron Levine
Georgia Institute of Technology

R&D Developmental Cycle in Indian ICT Sector – A Learning Cycle Showing Evidence of the Butterfly
Mary Mathew
Indian Institute of Science

Rethinking the Brain Drain: China's High Skilled Migration
Monica Yu Meng
Georgia Institute of Technology

Shifting Innovation Patterns in Emerging Economies: Alternative Energy/Cleantech in India as a Case in Point
Bala Mulloth
Polytechnic University

A Journey to the West: Strategic Capability Innovation of China-Based IT Outsourcing Firms
Ning Su
New York University

From Lab to Market: Strategies and Issues in the Commercialization of Nanotechnology in China
Jue Wang
Georgia Institute of Technology

Appendix C

PARTICIPANT BIOGRAPHIES

Dilip R. Ahuja
Dr. Ahuja is the ISRO Professor of Science and Technology Policy at the National Institute of Advanced Studies (NIAS) in Bangalore. At the time of the conference he was on a sabbatical at the United Nations Foundation in Washington, DC, as a senior policy advisor to the Global Leadership for Climate Action. He was also a special advisor to the InterAcademy Council's study titled, "Lighting the Way: Toward a Sustainable Energy Future". He has contributed to several reports of the Intergovernmental Panel on Climate Change. Prior to joining NIAS, he was a senior environmental specialist at the Global Environment Facility Secretariat. Dr. Ahuja obtained his doctorate from the University of Virginia at Charlottesville and his Bachelor's in Electrical Engineering from the Indian Institute of Technology, Bombay.

Venkatesh Rao Aiyagari
Dr. Aiyagari is currently the adviser and head of the Indian Science and Engineering Research Council (SERC)'s Seismicity Program, which is responsible for promoting R&D in newly emerging and frontier areas of science and engineering. The SERC has been making increasing efforts to promote basic research particularly in the universities and academic institutions and encouraging young scientists and engineers. Dr. Aiyagari specializes in the areas of operations research, systems analysis and industrial engineering problems. His professional interests include science and technology policy and planning, R&D program management, technology transfer studies, scientometrics, systems planning/operations research and business management analysis. He is involved in formulating policies and plans for the SERC activities related to the promotion of R&D in the country. He is also actively associated with the overall plans and programs of the DST covering R&D, technology development, science and society, and international S&T related activities. Dr. Aiyagari received his Ph.D. (hc) from Sri Krishna Devaraya University, Ananthapur. He also holds a master's degree in systems engineering and operations research from the Institute of Industrial Administration, Union College, New York. His bachelors degree is in mechanical engineering. He is a Fellow of the Indian National Academy of Engineering, New Delhi, and a member of the Engineering Staff College of India (ESCI), Institution of Engineers, India International Centre, and the Indian Habitat Centre, all in New Delhi.

Ashish Arora
Dr. Arora is a professor of economics and public policy in the Heinz School of Public Policy and Management at Carnegie Mellon University. He served as a co-director of the Software Industry Center at Carnegie Mellon University until 2006. He is on the editorial board of six academic journals, and has served on a number of committees for bodies such as the National Academy of Sciences and the Association of Computing Machinery. Dr. Arora's research focuses on the economics of technology and technical change. His research interests include the study of technology intensive industries such as software, biotechnology, and chemicals, the role of patents and licensing in promoting technology startups, and the economics of information technology.

Shamnad Basheer
Professor Basheer is a visiting associate professor at George Washington University and is also an associate with the Oxford Intellectual Property Research Centre and a Welcome Trust scholar in the doctoral program at Oxford. Professor Basheer has been an invited research

fellow at the Institute of Intellectual Property, Tokyo, an International Bar Association scholar, and an Inter-Pacific Bar Association scholar. He also has been an editor of the Oxford Commonwealth Law Journal and a founding member of the Electronic Database of Intellectual Property.

Patrick Canavan
Mr. Canavan is senior vice president, global governance for Motorola, where he provides consultation for the board of directors, Chairman and CEO and the senior leadership team on issues of corporate governance, globalization, and integration within Motorola. Mr. Canavan joined Motorola in 1980 as director of human resources with responsibility for Europe, the Middle East and Africa, headquartered in Geneva, Switzerland. He became the head of global leadership and organization development for the entire corporation in 1986, and assumed his present role in 2001. In 2004, he served as the acting head of human resources and in 2005 served as the acting chief information officer. In 1994-95, Mr. Canavan took an assignment as the regional president for Central and Eastern Europe, Middle East and Africa and created the strategy and infrastructure for Motorola's pursuit of growth in these emerging markets. He followed this later in 1995 and 1996 with a similar effort in Asia Pacific, working out of Hong Kong. Prior to joining Motorola, Mr. Canavan was director of management training and organization development for Digital Equipment Corporation in Europe from 1976 to 1980. Earlier, he served as assistant professor of organization development at the Center for Industrial and Institutional Development at the University of New Hampshire from 1972 to1976. He began his career teaching at Southern Methodist University in 1970. Mr. Canavan holds a Master of Philosophy degree in administrative science from Yale University, and a B.B.A. degree *summa cum laude* in finance from Iona College.

Cong Cao
Dr. Cao is a Senior Research Associate with the Neil D. Levin Graduate Institute of International Relations and Commerce, State University of New York, where he also coordinates Levin's Global Talent Index project. He received his Ph.D. in sociology from Columbia University in 1997 and has worked at the University of Oregon and the National University of Singapore. Dr. Cao is interested in the social studies of science and technology with a focus on China.

Ralph Cicerone
Dr. Cicerone, president of the National Academy of Sciences, is an atmospheric scientist whose research in atmospheric chemistry and climate change has involved him in shaping science and environmental policy at the highest levels nationally and internationally. In 2001, he led a National Academy of Sciences study of the current state of climate change and its impact on the environment and human health, requested by President Bush. During his early career at the University of Michigan, Dr. Cicerone was a research scientist and held faculty positions in electrical and computer engineering. In 1978, he joined the Scripps Institution of Oceanography at the University of California, San Diego as a research chemist. From 1980 to 1989, he was a senior scientist and director of the atmospheric chemistry division at the National Center for Atmospheric Research in Boulder, Colorado. In 1989, he was appointed the Daniel G. Aldrich Professor of Earth System Science at the University of California at Irvine and chaired the department of earth system science from 1989 to 1994. He served as dean of physical sciences for the next four years. Prior to his election as Academy president, Dr. Cicerone was the chancellor of the University of California at Irvine from 1998 to 2005. Dr. Cicerone received his bachelor's degree in Electrical Engineering from the Massachusetts Institute of Technology, where he was a varsity baseball player. Both his master's and doctoral degrees are from the University of Illinois in electrical engineering, with a minor in physics.

Charles L. Cooney
Dr. Cooney is currently the Robert T. Haslam Professor of Chemical Engineering at the Massachusetts Institute of Technology. His research focuses on biochemical engineering as the integration of biological science with engineering. An area of his long-term interest is

biochemical process control with recent emphasis on the application of expert systems, artificial neural networks and data reconciliation to fermentation and cell culture. A second focus is biochemical product recovery. As co-director of the Program on the Pharmaceutical Industry, a collaborative program with the Sloan School of Management, he is researching issues of competitiveness and productivity of the pharmaceutical industry. He is particularly interested in research that addresses manufacturing, management of technology and industry structure. The program's goal is to develop an understanding of the factors that drive and constrain the implementation of new manufacturing technology in the pharmaceutical industry. Dr. Cooney received his Ph.D. and S.M. from the Massachusetts Institute of Technology and his B.S. from the University of Pennsylvania.

Carl Dahlman
Dr. Dahlman is the Henry R. Luce Professor of International Relations and Information Technology at Georgetown University's Edmund A. Walsh School of Foreign Service. Dr. Dahlman joined the Georgetown faculty after more than 25 years of service at the World Bank. At Georgetown, Dr. Dahlman's research and teaching explore how rapid advances in science, technology and information are affecting the growth prospects of nations and influencing trade, investment, innovation, education and economic relations in an increasingly globalizing world. Previously, Dr. Dahlman served as Senior Advisor to the World Bank Institute. Dr. Dahlman also served as staff director of the 1998-1999 World Development Report, Knowledge for Development. In addition, he was the Bank's resident representative and financial sector leader in Mexico from 1994 to 1997, years during which the country coped with one of the biggest financial crises in its history. Before his position in Mexico, Dr. Dahlman led divisions in the Bank's private sector development, and industry and energy departments. He has also conducted extensive analytical work in major developing countries including Argentina, Brazil, Chile, Mexico, Russia, Turkey, India, Pakistan, China, Korea, Malaysia, Philippines, Thailand, and Vietnam. Dr. Dahlman earned a B.A. *magna cum laude* in international relations from Princeton University and a Ph.D. in economics from Yale University. He has also taught courses at Columbia University's School of International and Public Affairs.

Jason Dedrick
Dr. Dedrick is co-director of the Personal Computing Industry Center and project scientist at the Center for Research on Information Technology and Organizations (CRITO) at the University of California at Irvine. His research interests include the globalization of information technology and e-commerce, national IT policy, and the impacts of IT on organizational structure and economic performance. He is now studying the globalization and offshoring of knowledge work in the computer industry and its impacts on U.S. innovation and employment. His research has been supported by the National Science Foundation, the Alfred P. Sloan Foundation, the National Academies of Science and Engineering, and the IBM Corporation. He has consulted for major IT firms such as IBM, Intel, and CSC Consulting. He holds a Ph.D. in management from the University of California at Irvine, and a master's degree in Pacific International Affairs from the University of California at San Diego.

Marco Di Capua
Dr. Di Capua is currently executive director, Department of Energy China Office, U.S. Embassy, Beijing. Prior to holding this post, he was a physicist at Lawrence Livermore National Laboratory. There, he was responsible for Chinese affairs in the proliferation prevention and arms control group of the national security directorate. He was a commissioned officer in the Foreign Service of the United States assigned to the Foreign Service Institute, Washington, D.C. (1992–1993), and at the U.S. Embassy, Beijing (1993–1997), as counselor for science and technology affairs. He was attached to the U.S. Navy as a liaison scientist with the London unit of the Office of Naval Research from 1988 to 1990, where he analyzed R&D developments in Europe and the Soviet Union in a period of rapidly changing political and military environments. He developed an interest

in Asian affairs as an undergraduate in engineering physics at Cornell University. He holds a doctorate from Princeton University (1972).

Sean Dougherty
Mr. Dougherty is a China and India expert at the Organisation for Economic Co-operation and Development (OECD) in Paris, where he is senior economist in the economics department. He has co-authored the OECD's first economic surveys of both China (2005) and India (forthcoming, 2007), and is now leading an OECD-wide project to improve growth prospects in its member countries. He writes and speaks frequently on the Chinese and Indian economies, where he has lived and traveled extensively. Before joining the OECD in 2003, he was at The Conference Board in New York, where he carried out a study of global R&D performance, funded by the US National Science Foundation. Mr. Dougherty holds graduate degrees in economics and international relations, as well as a Bachelor of Science degree from the Massachusetts Institute of Technology.

Pete Engardio
Mr. Engardio is a Senior Writer for *Business Week*, focusing on global business and economic trends; however, at the time of the conference he was on leave at Harvard as a Wertheim fellow. Mr. Engardio joined *Business Week* in 1985 as a correspondent in the magazine's Atlanta bureau. In 1987 he moved to Miami as bureau manager. In 1990 he became a correspondent in the Hong Kong bureau, where he covered Asian business for six years. In 1996 he moved to New York as an Asian editor. From 1998 to 2001, he was editor of the Asian Edition. In 2005, Mr. Engardio anchored *Business Week*'s special issue "China & India: What You Need to Know," winner of the Institute for Political Journalism Award. Prior to joining *Business Week*, Mr. Engardio was a feature editor for *Business Korea* in Seoul. Before that, he worked for the Bay City News Service in San Francisco and the *San Francisco Bay Guardian*. In 2004, Mr. Engardio was a Reuters Journalism Fellow at Oxford University. He holds a B.A. from Central Michigan University and an M.A. from the University of Missouri School of Journalism.

Da Hsuan Feng
Dr. Feng is vice president for research and graduate education at the University of Texas at Dallas (UTD) and was named to the strategic science advisory board of New Economy Strategies (NES) in 2003. Dr. Feng, a theoretical physicist whose work has spanned the areas of international affairs, government service, business entrepreneurship and public education, was appointed UTD's first vice president for research and graduate education in November 2000. He earned a bachelor's degree in physics from Drew University and master's and Ph.D. degrees in theoretical nuclear physics from the University of Minnesota.

Richard Forcier
Mr. Forcier is an employee of Hewlett-Packard and is currently the director of engineering for the imaging and printing group R&D hub in India. In his 17 years with Hewlett-Packard, Mr. Forcier has worked both in a manufacturing role as well as in a research and development role. In both functions he has worked extensively with Asian countries including China, India, Singapore, Taiwan, Malaysia, and Indonesia. Over the years, Mr. Forcier has been involved in establishing many outsourced engagements in Asia in hardware, embedded software (firmware), and software. In his current position, he is working with a management team based in Singapore to establish an offshore R&D organization spanning Singapore, China, and India.

Mary L. Good
Dr. Good is the Donaghey University Professor at the University of Arkansas, Little Rock, and serves as the managing member for Venture Capital Investors, LLC, a group of Arkansas business leaders who expect to foster economic growth in the area through the opportunistic support of technology-based enterprises. Dr. Good also presently serves on the Board of Biogen, a successful biotech company in Cambridge Massachusetts; IDEXX Laboratories of Westbrook, Maine; and the Lockheed Martin

Energy Research Corporation Board of Oak Ridge, Tennessee. Previously Dr. Good served four years as the Under Secretary for Technology for the Technology Administration in the Department of Commerce. In addition to her role as Under Secretary for Technology, Dr. Good chaired the National Science and Technology Council's committee on technological innovation (NSTC/CTI), and served on the NSTC committee on national security. Before joining the Administration, Dr. Good was the senior vice-president of technology at Allied Signal, Inc. Dr. Good received her B.S. in chemistry from the University of Central Arkansas and her M.S. and Ph.D. degrees in inorganic chemistry from the University of Arkansas. She has also received numerous awards and honorary degrees from many colleges and universities, including most recently the College of William and Mary, Polytechnic University of New York, Louisiana State University, and Michigan State University.

Warren Harris
Mr. Harris holds an honors degree in mechanical engineering and is a chartered engineer. He started his career at Babcock Power, working in design and computational methods, before moving to INCAT in 1988. His roles at INCAT have progressed from software development and consulting to executive positions in both the United Kingdom and the United States. Since April 2007 he has been the company's CEO, overseeing operations worldwide, including the Asia-Pacific region.

Tony Hey
As corporate vice president of the external research division of Microsoft Research, Dr. Hey is responsible for the worldwide external research and technical computing strategy across Microsoft Corp. He leads the company's efforts to build long-term public-private partnerships with global scientific and engineering communities. His responsibilities also include working with internal Microsoft groups to build future technologies and products that will transform computing for scientific and engineering research. Dr. Hey also oversees Microsoft Research's efforts to enhance the quality of higher education around the world. Before joining Microsoft, Dr. Hey served as director of the U.K.'s e-Science Initiative, managing the government's efforts to provide scientists and researchers with access to key computing technologies. Before leading this initiative, Dr. Hey worked as head of the School of Electronics and Computer Science at the University of Southampton, where he helped build the department into one of the pre-eminent computer science research institutions in England. In addition, Dr. Hey has advised countries such as China, France, Ireland and Switzerland to help them advance their scientific agenda and become more competitive in the global technology economy. For his service to science, Dr. Hey received the award of Commander of the Order of the British Empire in the 2005 U.K. New Year's Honors List. Dr. Hey is a graduate of Oxford University, with both an undergraduate degree in physics and a doctorate in theoretical physics.

Trevor G. Houser
Mr. Houser is a Director at China Strategic Advisory (CSA), a specialized practice helping decision makers in the public and private sectors analyze and understand commercial, economic and policy trends in greater China. Mr. Houser leads CSA's energy sector activities, and splits his time between New York and China, where he meets regularly with government officials, business leaders, academics, and NGOs about developments in the energy arena. He is also responsible for seminars and presentations on overall China macroeconomic development and regularly advises policymakers in the U.S. regarding China's economic growth. Mr. Houser is also a visiting fellow at the Colin Powell Center for Policy Studies at the City College of New York, where his research focuses on analyzing trends in China's energy sector and the affects on international markets, the global environment and relations with the United States.

Kent Hughes
Dr. Hughes is currently director of the program on Science, Technology, America and the Global Economy at the Woodrow Wilson International Center for Scholars. Prior to joining the Center, Dr. Hughes served as the

Associate Deputy Secretary at the U.S. Department of Commerce, President of the Council on Competitiveness, and held a number of senior positions with the U.S. Congress, where he focused on international economic issues and the question of long-term American economic strength. These positions include, chief economist to U.S. Senate Majority Leader Robert Byrd, senior economist of the Congressional Joint Economic Committee, and legislative and policy director in the office of U.S. Senator Gary Hart during the Senator's first presidential campaign. Prior to his congressional service, Dr. Hughes served as a staff attorney for the Urban Law Institute, a poverty law firm established to provide counsel to national and local groups. Dr. Hughes holds a Ph.D. in economics from Washington University, an LL.B. from Harvard Law School, and a B.A in political and economic institutions from Yale University.

Soonhee Jang
Ms. Jang is a patent counsel and regional IP counsel for Asia at Eli Lilly and Company. Ms. Jang has a full range of patent experience and responsibilities in managing and enforcing patent rights in Asia, including China, Korea, Taiwan and India. She also serves as principle attorney handling IP issues involving outsourcing projects in Asia. As an in-house counsel, she has managed patent portfolios, which cover commercially important pharmaceutical products, and she provides legal counseling, opinions and patent/litigation strategies. Ms. Jang is a vice chair of the Asian practice committee of Intellectual Property Owners Association (APC-IPO), a member of AIPLA-Japan Practice Committee and AIPLA-IP Practice Far East Committee. She organized and led the US delegations of APC-IPO to China for fact-finding trips where the delegations discussed many pressing IP issues with the Chinese courts, governmental and nongovernmental agencies, as well as Chinese IP organizations. She also organized and co-chaired a program involving IP enforcement in China for the first IPO-JIPA Asian Practice International Congress held in Seattle, Washington in 2005. Ms. Jang is registered to practice before the United States Patent and Trademark Office and is a member of the federal and state bars of New Jersey. Ms. Jang received her law degree from Franklin Pierce Law Center, her undergraduate degree in chemistry from California State University at Fresno, and a master's degree in chemistry from the University of Washington.

James W. Jarrett
Mr. Jarrett is vice president of legal and corporate affairs and director of global public policy for the Intel Corporation. Prior to his current position, Mr. Jarrett was president of Intel China, Ltd., based in Beijing 1996-2000. Mr. Jarrett joined Intel in 1979 as the company's first manager of corporate communications, and was named a vice president in 1987. From 1994-96 he served as vice president of investor relations. Prior to Intel, he worked for two New York-based communications counseling firms, and served with the U.S. Army at the U.S. Military Academy, West Point, New York. He is a graduate of Kenyon College, Gambier, Ohio.

Devesh Kapur
Professor Devesh Kapur was appointed director of the Center for the Advanced Study of India, University of Pennsylvania in 2006. He is an associate professor of political science at the University of Pennsylvania, and holds the Madan Lal Sobti Professorship for the Study of Contemporary India. Prior to joining the university, Professor Kapur was associate professor of government at the University of Texas at Austin, and before that the Frederick Danziger associate professor of government at Harvard. His research focuses on human capital, national and international public institutions, and the ways in which local-global linkages affect political and economic change in developing countries. Professor Kapur has focused in particular on India and the impact of international institutions and diasporas on India. He holds a BTech in chemical engineering from the Institute of Technology, Banaras Hindu

University; an MS in chemical engineering from the University of Minnesota, and a Ph.D. from the Woodrow Wilson School at Princeton.

Martin Kenney

Dr. Kenney is a professor at the University of California at Davis and a senior project director at the Berkeley Roundtable on the International Economy. He is a fellow at the Center for Entrepreneurship at Davis. He has published five books and over 120 scholarly articles on the development of Silicon Valley, venture capital, university-industry relations, and the globalization of services. He was a visiting professor at the Copenhagen Business School, Cambridge University, Hitotsubashi University, Kobe University, and Tokyo University. He has consulted for or presented to various organizations including the InterAmerican Development Bank, the World Bank, President's Council of Advisors on Science and Technology, National Academy of Engineering and National Academy of Sciences, Association of Computing Machinery, and the OECD and consulted for various private firms. His research has been supported by the National Science Foundation, the Sloan Foundation, and the Kauffman Foundation.

Rishikesha T. Krishnan

Rishikesha T. Krishnan is a professor in the corporate strategy and policy area at the Indian Institute of Management, Bangalore (IIMB), India. His research interests are in the areas of strategy, innovation and competitiveness. He is currently the chairperson of research and publications, and of IIMB's Centre for Development of Cases and Teaching Aids. He was earlier the chairperson of the postgraduate program in management at IIMB. Prof. Krishnan has been a consultant to, or conducted management development programs for, British Telecom, Daimler Chrysler, Wipro, Siemens, Sasken Communication Technologies, the Murugappa Group, the Aditya Birla Group, Kochi Refineries and the Governments of India and Karnataka. Prof. Krishnan worked for four years as the general manager of a small high technology company in the telecom sector from 1987-91. During this period, he also co-founded a software company working on specialized engineering application software. From March 2001 to October 2001, he worked with a software product start-up founded by an IIMB alumnus. Prof. Krishnan obtained an M.Sc. degree in physics (5-year integrated program) from the Indian Institute of Technology at Kanpur and an M.S. degree in engineering-economic systems from Stanford University. His doctoral qualification was obtained from the Indian Institute of Management Ahmedabad, where he won the outstanding thesis proposal award instituted by the Industrial Finance Corporation of India.

Nicholas R. Lardy

Mr. Lardy is a senior fellow at the Peterson Institute for International Economics in Washington, D.C. Mr. Lardy joined the Institute in March 2003 from the Brookings Institution, where he was a senior fellow in the Foreign Policy Studies Program from 1995 until 2003 and served as interim director of Foreign Policy Studies in 2001. Prior to his work at Brookings, he was the director of the Henry M. Jackson School of International Studies at the University of Washington from 1991–95. From 1997 through the spring of 2000, he was also the Frederick Frank Adjunct Professor of International Trade and Finance at the Yale University School of Management. He is an expert on Asia, especially the Chinese economy. Before his directorship, Mr. Lardy had been a professor of international studies at the University of Washington from 1985 and an associate professor from 1983–85. He served as chair of the China Program from 1984–89. He was an assistant and associate professor of economics at Yale University from 1975–83.

Sandra Lawson

Ms. Lawson is a vice president and senior global economist at Goldman Sachs in New York. Her work focuses on long-term global trends such as the rise of the BRIC economies, globalization, capital markets development, demographics and trade. She publishes a monthly report on the BRICs and is also responsible for economics research for corporate clients. Ms. Lawson joined Goldman Sachs as an equity strategist monitoring legal and regulatory developments across East Asia during the 1997-1998 financial crisis. She has subsequently worked as an economist in both London and New York. She has degrees from the Yale Law School and Dartmouth College.

Vincent Ling
Dr. Ling is currently the vice president of molecular biology at Dragonfly Sciences. Prior to that, he was the director of molecular biology and genetics at Compound Therapeutics. He has thirteen years of industrial biotechnology experience related to the design, construction, screening and testing of novel recombinant protein therapeutics. Dr. Ling spent ten years as a member of the immunology department at Wyeth (formerly Genetics Institute), with two issued patents related to the discovery and application of protein therapeutics. He is an expert in developing protein therapeutics-related HTP screening systems, fusion-partners, modified active domains, and molecular evolution. Dr. Ling was a post-doctoral fellow and NASA research associate at Harvard Biolabs. He received his Ph.D. in plant biology at the University of Illinois at Urbana-Champaign, and his B.A. in Molecular Biology from the University of California at Berkeley.

Paul McCarthy
Based in New York and Detroit, Mr. McCarthy is a director in PwC's transaction services strategy group, specializing in the automotive sector. Mr. McCarthy has over 11 years experience in the auto industry. In the past, he has worked at a major OEM, as automotive lead for PwC Germany's advisory strategy services, in the leadership team of PwC AUTOFACTS, and in PwC's management consulting services. In addition to Germany, Mr. McCarthy has been involved in PwC automotive projects in China, India, Japan, Korea, Great Britain, Italy, Canada, and Mexico.

Jai Menon
Dr. Menon is IBM Research's leading authority on the design and architecture of data storage systems, which enable enterprises and organizations to manage their data reliably and efficiently. A native of Kerala, India, Menon received a bachelor of technology degree in electrical engineering from the Indian Institute of Technology, Madras, India in 1977. He earned a master of science and Ph.D. degrees in computer science from Ohio State University in 1978 and 1981, respectively. In 1982, Dr. Menon joined IBM Research in San Jose, Calif., where he became a pioneering researcher and designer of data storage systems and RAID (Redundant Array of Independent Disks) architectures. He was named functional manager, storage systems and server technology in April 2000. In May 2001, Dr. Menon was named IBM Fellow, the company's most prestigious and highest technical honor. He is also co-director of the Storage Systems Institute, a virtual organization/joint program between IBM Research and the storage systems division aimed at speeding the incorporation of scientific and technological advances into IBM storage systems products. Dr. Menon is an IEEE Fellow and member of the IBM Academy of Technology.

Harkesh K. Mittal
Mr. Mittal is the advisor and head of India's National Science and Technology Entrepreneurship Development Board. He was instrumental in establishing institutions of entrepreneurship development at the state level. He then moved on to provide technical and management consultancy to SME. Between 1990 and 2003, he was responsible for initiating various new programs in NSTEDB and also had a short stint with UNIDO for development of industrial clusters in India. At present he also looks after the work relating to plan-coordination, Swarnajayanti fellowships and information technology for the Department of Science and Technology. Mr. Mittal is currently also the national director of the UNDP project on SKILLS which aims to demonstrate that jobs can be created through appropriate location-specific, need-based, competency-linked training interventions using conventional as well as on-line systems. He has been responsible for establishing networks with international development institutions like the World Bank (InfoDev Programme) and European Union. At the national level he has linked activities of the NSTEDB with various developmental ministries and institutions. He holds a graduate degree in

dairy technology from National Dairy Research Institute (NDRI), Karnal and a master's degree in management from the Indian Institute of Management, Ahmedabad.

David Morgenthaler
Mr. Morgenthaler is the founding partner of Morgenthaler Ventures. He has served as a director, chairman, or president of more than 30 companies, and over the last 38 years he has built a national reputation for industry leadership and value-added venture capital investing. He served from 1977 to 1979 as the president and then chairman of the National Venture Capital Association (NVCA). In 1998, he received the first Lifetime Achievement Award by the NVCA for his work in venture capital, and has been elected to the Venture Capital Hall of Fame. In addition, he was an advisor to Brentwood Associates, a limited partner in Hambrecht & Quist, and is an emeritus trustee and distinguished fellow of The Cleveland Clinic Foundation. In 2004 he received the first life-time achievement award granted by the International Business Forum and was made one of the first two Kaufman Foundation Honorary Fellows. He is a member of the Science, Technology and Economic Policy Board of the National Academies. From 1957 until 1968, Mr. Morgenthaler was CEO of Foseco, Inc., manufacturer of specialty chemicals financed by J.H. Whitney & Co. Earlier in his career, Mr. Morgenthaler was a member of the management team of several young growth companies. He received both B.S. and M.S. degrees in mechanical engineering from the Massachusetts Institute of Technology.

Mu Rongping
Dr. Mu is now director-general and professor at the Institute of Policy and Management (IPM) of the Chinese Academy of Sciences (CAS) and director-general of the CAS Center for Innovation and Development and the CAS Center for Evaluation Research. He is also editor-in-chief of the *Chinese Journal of Science Research Management* (an academic bimonthly), vice president and secretary-general of the China High-tech Industry Promotion Society (CHIPS), and vice president of S&T Policy Research at the Chinese Association for Science. Prior to these roles, Dr. Mu worked as teacher in Hefei Poly-Technical University for four years. He has led more than 20 research projects commissioned or financed by the National Commission for Development and Reform, the Ministry of Science and Technology, National Natural Science Foundation of China, and CAS. His research interests are in S&T strategy and policy, S&T management and evaluation, technology foresight, and evaluation of international competitiveness of high-tech industry. Dr. Mu received his B.Sc. and M. Sc. degrees from the University of Science and Technology of China, and his Ph.D. from Technische Universität Berlin, Germany.

Norman Neureiter
Dr. Neureiter previously served as science and technology advisor to U.S. Secretary of State Colin Powell. As director of the AAAS Center for Science, Technology and Security Policy, he oversees an ambitious effort to build new connections between scientists, research institutions and the federal policy-makers who are involved with antiterrorism efforts and other national security issues. He holds a bachelor of science in chemistry from the University of Rochester (N.Y.). He was a Fulbright Fellow to Germany in 1955-56. He earned a Ph.D. in organic chemistry at Northwestern University in 1957. After joining the U.S. Foreign Service in 1965, during the height of the Cold War, he became the first U.S. science attaché in Eastern Europe in 1967, based at the U.S. Embassy in Warsaw, Poland. From 1969 to 1973, he served as the international affairs assistant in President Richard Nixon's Office of Science and Technology. After leaving that post, he worked for Texas Instruments until 1996 as director of Texas Instruments in Japan and vice president of Texas Instruments Asia. In the closing months of President Bill Clinton's administration he was named as science and technology adviser for a three-year term, first to Secretary of State

Madeleine Albright and then to Secretary Colin Powell. Dr. Neureiter left the post in September 2003 after his term expired.

Arvind Panagariya
Professor Panagariya is a professor of economics and co-director, Center for International Economics, University of Maryland at College Park. He holds a Ph.D. in economics from Princeton University. In the past he has served as the chief economist of the Asian Development Bank and also advised the World Bank, IMF, WTO, and UNCTAD in various capacities. Professor Panagariya has written extensively on trade reforms in developing countries. He is the founding editor of the *Journal of Policy Reform*, which he edited with Dani Rodrik during 1996-2001. He is currently an associate editor of *Economics and Politics*. He writes a monthly column in the *Economic Times*, India's top financial daily. He has also written guest columns in the *Financial Times, Hindu, India Today* and *Outlook*.

Thomas Pickering
Thomas Pickering is senior vice president for international relations at the Boeing Company, a position he assumed in January 2001 upon his retirement as United States Under Secretary of State for Political Affairs. Ambassador Pickering held the personal rank of career ambassador, the highest in the U.S. Foreign Service. In a diplomatic career spanning five decades, he has served as U.S. ambassador to the Russian Federation, India, Israel, El Salvador, Nigeria and the Hashemite Kingdom of Jordan. From 1989 to 1993, he served as ambassador to the United Nations. His government service began in 1956 in the Navy. On active duty until 1959, he later served in the Naval Reserve to the grade of lieutenant commander. Between 1959 and 1961, he served in the Bureau of Intelligence and Research of the State Department, and in the Arms Control and Disarmament Agency.

Sam Pitroda
Mr. Pitroda is the chairman and CEO of World-Tel Limited, an International Telecom Union (ITU) initiative. He is also the chairman and founder of Sevend High-Technology. Mr. Pitroda is also the founding chairman of a non-profit Foundation for Revitalization of Local Health Traditions in India. Mr. Pitroda received a master's degree in physics and electronics in Baroda, India. In 1964, he completed his master's degree in electrical engineering in Chicago. Thereafter, he worked at GTE and formed Wescom Switching, Inc. In 1984, Mr. Pitroda returned to India and founded the Center for Development of Telematics (CDAC) and later became advisor to the Indian Prime Minister on national technology policy.

V.S. Ramamurthy
After obtaining his M.Sc. degree from Madras University in 1963, Professor Ramamurthy joined the Training School of the then Atomic Energy Establishment, Trombay (the present Bhabha Atomic Research Centre). Since then, he has been engaged in full time research in nuclear physics and has made important contributions, both experimental and theoretical, in the areas of nuclear fission, statistical and thermodynamic properties of nuclei and medium energy heavy ion reaction mechanisms. Part of his work on fission theory earned him the Ph.D. degree from Bombay University in 1971. In 1989, he moved to the Institute of Physics, Bhubaneshwar, as director. After the installation and commissioning of a 3 MV pelletron accelerator at the Institute, he initiated several experimental programs on low energy ion beam applications and small atomic clusters. He also initiated an experimental high energy physics programme at the Institute using the accelerator in CERN, Geneva. In July 1995, Professor Ramamurthy assumed the position of Secretary, Department of Science and Technology, government of India.

J. Thomas Ratchford
Before joining George Mason University in 1993, Dr. Ratchford was associate director for policy and international affairs at the White House Office of Science and Technology Policy (OSTP). Prior to confirmation by the Senate to his OSTP position in 1989, he was the associate executive officer of the American Association for the Advancement of Science (AAAS). Dr. Ratchford is also CEO of STTA, LC. A condensed matter physicist, Dr. Ratchford has

served on university faculties and research staffs of private and governmental laboratories. As a professional staff member and subcommittee staff director of the House of Representatives' Committee on Science in the 1970s, he was one of the first scientists to serve the Congress full-time. He was selected a congressional fellow of the American Political Science Association, a fellow of the AAAS and the American Physical Society (APS), and a member of the Council on Foreign Relations. He is active in international science and technology programs in the U.S., Asia, and Europe, and chairs the U.S. side of the U.S.-China Science Policy Initiative for the National Science Foundation. Dr. Ratchford directs The George Mason University Law School's Tech Center's Science and Trade Policy Program. Dr. Ratchford received both his Ph.D. and M.A. from the University of Virginia in physics and also holds a B.S. in mathematics and physics from Davidson College.

Bhaven Sampat
Dr. Sampat's research centers on the economics of biomedical innovation, the law and economics of the patent system, and science policy. His current projects examine the political economy of the National Institutes of Health, the effects of patents on access to medicines in India, the interactions between patent laws and FDA regulation in the pharmaceutical industry, the determinants of patent quality in the U.S. patent system, and challenges to evidence-based medicine in contexts of rapid technological change. Dr. Sampat received his B.A. in economics and political science *summa cum laude* and with honors from Columbia University in 1996, and was awarded the Sanford Parker Prize in economics that year. He received his M.A. and Ph.D. with distinction in Economics from Columbia in 1998 and 2001. From 2001 to 2003, Dr. Sampat was an assistant professor at the School of Public Policy at the Georgia Institute of Technology. From 2003-2005 he was a Robert Wood Johnson Foundation Scholar in health policy research at the University of Michigan.

Adam Segal
Adam Segal is the Maurice R. Greenberg senior fellow for China studies at the Council on Foreign Relations. An expert on Chinese domestic politics, technology development, foreign policy, and security issues, Dr. Segal currently leads a study group on Asian innovation and technological entrepreneurship. Previously, he was the project director for a Council-sponsored independent task force on Chinese military modernization. Before coming to the Council, Dr. Segal was an arms control analyst for the China Project at the Union of Concerned Scientists. There, he wrote about missile defense, nuclear weapons, and Asian security issues. He has been a visiting scholar at the Massachusetts Institute of Technology's Center for International Studies, the Shanghai Academy of Social Sciences, and Qinghua University in Beijing. He has taught at Vassar College and Columbia University. Dr. Segal has a Ph.D. and a B.A. in government from Cornell University and an M.A. in international relations from the Fletcher School of Law and Diplomacy, Tufts University.

Oded Shenkar
Oded Shenkar is the Ford Motor Company Chair in Global Business Management and professor of management and human resources at the Fisher College of Business, Ohio State University, where he is also a member of the Center for Chinese Studies. Professor Shenkar's research interests include international business, particularly comparative and international management. His special interests include strategic and managerial issues pertaining to international strategic alliances. Geographically, his main region of interest is East Asia, particularly China. Professor Shenkar serves on the editorial boards of the *Academy of Management Executive, Journal of Cross-Cultural Management, Journal of International Business Studies, Journal of Management Inquiry, Management International Review, Human Relations* and *Organization Studies.* Professor Shenkar has advised multinational

firms, national and state governments, and international organizations. He is a member of the Conference Board Council of Integration Executives.

Denis Simon
Dr. Simon is the provost and vice president for academic affairs of the Levin Graduate Institute of International Relations and Commerce at the State University of New York. He has also served as managing director in Singapore for Scient and associate partner at Andersen Consulting China, and from 1990 to 1995 served as president of China Consulting Associates. Dr. Simon, who has published several books on China, including *Corporate Strategies Towards the Pacific Rim*, holds an M.A. and a Ph.D. from the University of California at Berkeley.

Roy Singham
Mr. Singham is founder and chairman of ThoughtWorks, Inc. With more than 20 years of technology and executive management experience, Mr. Singham is a globally-renowned information technology thought leader. He has authored technology-related columns in various industry publications, and is a frequent speaker at technology conferences worldwide. Mr. Singham and ThoughtWorks are recognized experts in enterprise architecture, agile development, large scale software development including highly distributed teams, open source software, ruby, .NET and web services. During the last five years, Mr. Singham has provided management services to clients in the insurance, mortgage, energy, leasing, retail and software development industries. He has also directed multi-million dollar projects for clients including Caterpillar Financial Services, Dixonis Group, Progressive Insurance, and Transamerica. One of Mr. Singham's passions is evolving cultural and organizational patterns to create the most advanced internally and externally socially networked consultancies in the industry.

Bruce Stokes
Mr. Stokes is the international economics columnist for the *National Journal*, a Washington-based public policy magazine and, a journalism fellow at the German Marshall Fund. In addition, Mr. Stokes is a fellow with the Pew Research Center, where he works on the Global Attitudes Project, a survey of 48,000 people in 50 countries on changing public values and attitudes toward a range of issues, including globalization, modernization, democratization, and current foreign policy concerns, including America's role in the world. Mr. Stokes is a regular commentator for Marketplace on National Public Radio. He is also the U.S. rapporteur for the Transatlantic Policy Network, and from 1996 to 2002, he was a senior fellow at the Council on Foreign Relations. He is currently working on a study for the Centre for European Reform on transatlantic economic relations.

Pete Suttmeier
Dr. Suttmeier a professor of political science, received his Ph.D. from Indiana University in 1970 and has been with the University of Oregon since 1990. He is a member of the Department of Commerce Civil Industrial Technology Coordinating Committee for relations with the Chinese Ministry of Science and Technology and has served as a senior analyst at the congressional Office of Technology Assessment, as a consultant to the World Bank and the UNDP, and as the director of the Beijing Office of the Committee for Scholarly Communication with China. Dr. Suttmeier's current research includes a study of China's scientific community (with Cao Cong), and a longer term study of Chinese approaches to the management of technological and environmental risks entitled, *Is It Safe to be Modern?*

Lee S. Ting
Mr. Ting is a managing director of W.R. Hambrecht & Co. Mr. Ting is a former corporate vice president of Hewlett Packard where he worked for more than thirty years. He was the founder and general manager of HP Taiwan, general manager of Far East region, managing director of Southeast Asia operations, director of business development, and vice president and managing director of Asia Pacific. His last position was corporate vice president and managing director of worldwide geographic operations where he was responsible for HP's customer-facing organizations in all the

countries in which the company had a business presence. He is an independent board member of the Lenovo Group, the leading IT company in China, and MTI, a supplier of satellite/microwave communications components and subsystems based in Taiwan. Mr. Ting is also an advisor to WK Technologies, a leading venture capital company with operations in Taiwan and the United States and other private companies. Mr. Ting received his BSEE from the Oregon State University and has completed the Stanford Executive Program.

Vivek Wadhwa
Mr. Wadhwa is founder, chairman, and CEO of Relativity Technologies, Cary, North Carolina. His company does what is called legacy transformation, creating software to ensure old computers are compatible with newer client-servers and the Web. He is also president of the Carolinas chapter of The Indus Entrepreneurs (TIE), a non-profit global network intended to foster entrepreneurship. In addition, he serves as an advisor to several local entrepreneurs looking to build companies from the ground up. Mr. Wadhwa has over 25 years of experience in the software industry. He has focused on the issue of coping with technological change since he was vice president of information services at New York-based investment banking powerhouse CS First Boston (CFSB). He spearheaded the development of a revolutionary technology for building large-scale client/server systems. The technology was so successful that CSFB decided to spin off this business unit into its own company, Seer Technologies. Mr. Wadhwa was tapped to head Seer's technology efforts as executive vice president and chief technology officer, and helped grow the nascent startup into a $118 million publicly traded company. Mr. Wadhwa was born in Delhi, India, and came to the United States in 1980. He holds a B.A. degree in computer science from Canberra University in Australia and a master's degree in business administration from New York University.

Kuan Wang
Dr. Wang currently serves multiple roles at the National Institutes of Health. He is lab chief in the Laboratory of Muscle Biology, Section Chief of Muscle Proteomics and Nanotechnology, and he focuses on Musculoskeletal and Skin Diseases at the National Institute of Arthritis. Prior to these roles, he served as lab chief in the Lab of Physical Biology. He has also been a visiting professor in the department of cell biology at Duke University Medical Center and, prior to that, a professor in the department of chemistry and biochemistry at the University of Texas at Austin. He was an Established Investigator of the American Heart Association. He is part of the National Institute of Health's Nanomedicine Roadmap Implementation Group and serves on the editorial board of the *Journal of Nanomedicine*. He also currently serves on the advisory board of Taiwan's National Research Council and on several advisory boards of Taiwan's Academia Sinica. He completed his postdoctoral training in cell and molecular biology in 1976 at the University of California at San Diego. He earned his Ph.D. in molecular biochemistry and biophysics at Yale University, completed graduate studies in physical chemistry at the State University of New York, Stony Brook, and earned his B.S. in chemistry from National Taiwan University.

Alan Wm. Wolff
Alan Wolff is a member of Dewey & LeBoeuf's management committee and managing partner of the firm's Washington, D.C., office. He also leads Dewey's international trade practice group representing clients involved in some of the most important trade issues of our day. It has been credited with helping to open international markets for American products, including semiconductors, computer parts, telecommunications equipment, soda ash and forest products, consumer photographic film and paper, and insurance, and other services. The trade practice group is also active in efforts to limit trade-distorting practices such as dumping

and subsidies, private anticompetitive practices, violations of intellectual property rights, and trade-related investment performance requirements. Mr. Wolff served as United States Deputy Special Representative for Trade Negotiations (1977 - 1979) in the Carter Administration, holding the rank of ambassador, after having served as general counsel of the agency from 1974-1977. As Deputy Trade Representative, he played a key role in the formulation of American trade policy and its implementation. From 1968 to 1973, Mr. Wolff was an attorney dealing with international monetary, trade and development issues at the Treasury Department.

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Balaji Yellavalli
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Stephen A. Merrill, *Project Director*
Dr. Merrill has been Executive Director of the National Academies' Board on Science, Technology, and Economic Policy (STEP) since its formation in 1991. The STEP program addresses macroeconomic, intellectual property, technical standards, trade, taxation, human resources, and statistical as well as research and development policies affecting technology development and economic performance. Previously, Dr. Merrill was a fellow in international business at the Center for Strategic and International Studies (CSIS), served on various congressional staffs, including that of the Senate Commerce, Science, and Transportation Committee. Dr. Merrill holds degrees in Political Science from Columbia (B.A., *summa cum laude*), Oxford (M. Phil.), and Yale (M.A. and Ph.D.) Universities.