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Propelled by open markets and economic reform, the 1990s brought unparalleled growth and economic development to the People's Republic of China. At the same time, but less widely known, China has begun to assume an influential role in the globalization of high-tech research and development (R&D). Consequently, the PRC is poised to become not only Asia's assembly line, but also one of the Pacific Rim's — and the world's — centers of innovation.

A growing number of the world's leading high-tech multinationals have established R&D programs or centers in China, raising many questions for US policymakers regarding the benefits and risks of overseas R&D in terms of near- and long-term US security and economic interests. Although there are clear mutual advantages in cross-national R&D collaboration, technology transfers to the PRC carry potential risks as uncertainty lingers about the future direction of Sino-US relations.

This study examines in detail high-tech R&D programs in two key industry sectors — telecommunications and computer technology. Because most high-tech R&D today is conducted by commercial enterprises and is a leading indicator of future industrial and technological capabilities, it is important for US policymakers to understand more about this growing trend. A greater understanding of the true nature of these activities and a careful weighing of the benefits and risks of foreign-funded, high-tech R&D in China will aid policymakers in crafting prudent and balanced policies serving both US national security and economic interests.

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FOREIGN HIGH-TECH R&D IN CHINA: Risks, Rewards, and Implications for U.S.-China Relations

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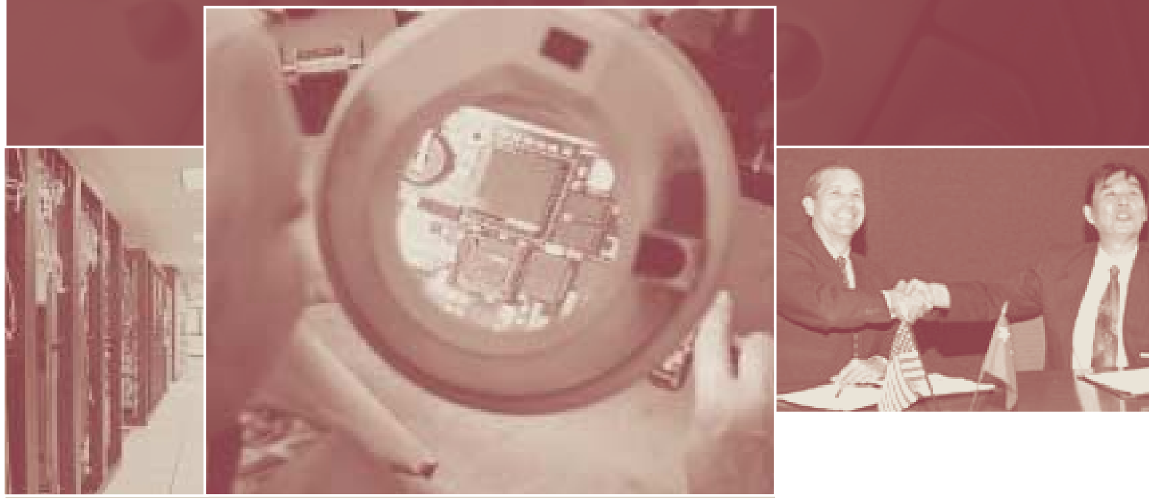
Foreign High-Tech R&D in China

RISKS, REWARDS, AND IMPLICATIONS FOR U.S.-CHINA RELATIONS



Kathleen Walsh

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RISKS, REWARDS, AND IMPLICATIONS FOR U.S.-CHINA RELATIONS

Kathleen Walsh

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Foreword

I am pleased to present the latest publication of the Henry L. Stimson Center, *Foreign High-Tech R&D in China: Risks, Rewards, and Implications for US-China Relations*. This study explores the confluence of two key aspects of the architecture of international relations in the 21st century—globalization and an increasingly trade-oriented conception of national security—within the specific context of foreign high-tech research and development in China. As the study explains, global R&D is a relatively new mechanism of technology transfer with potentially great economic and security implications for all parties involved. The study examines the nature of this global trend and weighs the risks assumed and rewards conferred by this activity for both national governments and multinational corporations. The report proposes useful steps that the United States and other countries can take to better understand and monitor global R&D and avoid outcomes that could prove harmful to US national and economic security interests in the years to come.

This study adds a new dimension to the Stimson Center's core mission to examine national and international security issues by exploring the increasingly important linkages between trade and security. It also complements the Center's ongoing work on China: its evolving role in the international system and its relations with the United States. While this study focuses its R&D story on implications for the US-China relationship, the issue is really broader and global in its potential impact.

It is our hope that this study will be helpful in focusing attention on the nexus between trade and security and in deepening our knowledge of a new trend that will shape future trade and security policies. The Project Director, Kathleen Walsh, and I are grateful for the support we received from the Smith Richardson Foundation for this project.

We will welcome hearing from you if you have any questions about this project or other work on Asian security issues at the Stimson Center.

Ellen Laipson
President and CEO
The Henry L. Stimson Center

Tables and Figures

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Abbreviations and Acronyms

3G	Third-generation
3GPP	Third Generation Partnership Project
AeA	American Electronics Association
CAS	Chinese Academy of Science
CCF	China-China-Foreign (telecom industry partnership)
CDMA	Code Division Multiple Access
CERNET	China Education and Research Network
COSTIND	Commission on Science and Technology in the National Defense (PRC)
DOC	Department of Commerce
DoD	Department of Defense
DVD	Digital Versatile Disc
ETDZ	Economic and Technological Development Zone
EU	European Union
FBIS	Foreign Broadcast Information Service
FDI	Foreign Direct Investment
FTZ	Foreign Trade Zone
GAD	General Armament Department (PRC)
GDP	Gross Domestic Product
GERD	Gross Expenditure on R&D
GSM	Global System for Mobile Communications (telecom)
HDTV	High-definition Television
HTDZ	High Technology Development Zone
HTS	Harmonized Tariff Schedule
ICT	Information Communications Technology
IT	Information Technology
IPR	Intellectual Property Rights
KIP	Knowledge Innovation Program (CAS)
JV	Joint Venture
MII	Ministry of Information Industry
MNC	Multinational Corporation

MOFTEC	Ministry of Foreign Trade and Economic Cooperation*
MOST	Ministry of Science and Technology (PRC)
NAICS	North American Industrial Classification System
NERC	National Engineering Research Center
NSB	National Science Board
NSF	National Science Foundation (US)
NSFC	National Natural Science Foundation (PRC)
NSI	National System of Innovation
NTE	New Technology Enterprise
OECD	Organization for Economic Cooperation and Development
PCAST	President's Council of Advisors on Science & Technology
PDA	Personal Digital Assistant
PLA	People's Liberation Army (PRC)
PNTR	Permanent Normal Trade Relations
PRC	People's Republic of China
R&D	Research and Development
SAPI	Strategic Action Plan for S&T Innovation
SCITO	State Council Informatization Office
SEZ	Special Economic Zone
SIC	Standard Industrial Classification
SIPO	State Intellectual Property Office (PRC)
SITC	Standard International Trade Classification
S&T	Science and Technology
TD-SCDMA	Time Division–Synchronous Code Division Multiple Access (telecom)
UN	United Nations
UNCTAD	United Nations Conference on Trade and Development
US	United States
W-CDMA	Wide-band Code Division Multiple Access (telecom)
WFOE	Wholly Foreign-Owned Enterprise
WTO	World Trade Organization

* This Ministry is to be folded into the new Ministry of Commerce, as announced following the 2003 session of the Chinese National Peoples' Congress.

Acknowledgments

This publication would not have been possible but for the support, assistance, guidance, and insights of numerous colleagues, friends, and others. While many of those interviewed and consulted for this study cannot be identified since their insights were given confidentially, their contribution to this work and the author's understanding of rapidly changing conditions in the China market were invaluable. The findings, views, and any errors presented in this publication, however, are solely those of the author.

For the able research and administrative assistance provided by Scoville Fellow Jonathan Davis as well as by research interns Ji Huishu, Sarah Terbrueggen, and Richard Pearson, the author is especially grateful.

This project also would not have started, much less been completed, were it not for the assistance, advice, and generosity of numerous colleagues at the Henry L. Stimson Center, whose support from beginning to end was greatly appreciated.

Finally, particular appreciation goes to the Smith Richardson Foundation, whose generous support and willingness to take a chance made this study possible.[1]

[1] This effort was sponsored by the Smith Richardson Foundation under Grant No. 20011895. The views and conclusions contained herein are those of the author and should not be interpreted as representing the official policies or endorsements, either expressed or implied, of either the Stimson Center or the Smith Richardson Foundation.

Executive Summary

Commercial research and development in high-tech industries has become an increasingly global undertaking. Over the past two decades, the number of US and other overseas R&D centers has multiplied, although it is unclear exactly how far and how fast this trend is developing due to the still very limited data on this phenomenon. What is clear is that these activities have spread from the industrialized economies to parts of the developing world. The People's Republic of China, in particular, has attracted scores of foreign-funded, high-tech R&D investment from around the globe, particularly in sectors related to information communications technology. This report examines the emergence and evolution of foreign-invested R&D centers in China with a focus on the computer and telecommunications industries. The study's key findings include the following:

- Globalization and the international distribution of high-tech R&D have aided China's efforts to develop its commercial industry. Increasingly, foreign investors are competing with local high-tech enterprises for market share in the computer and telecommunications sectors.

- During nearly two decades of reforms and restructuring, PRC officials have sought to accelerate S&T modernization through the acquisition of foreign, especially Western, technologies and know-how. To date, these efforts have yielded some impressive results, but China still has a long way to progress before achieving parity with the S&T capabilities of most industrialized economies or before reaching its goal of implementing a "national system of innovation."

- The PRC government encourages foreign R&D investment in China, particularly in information technology-related industries, by offering a range of preferential policies that include tax rebates, construction loans, access to modern facilities, and other incentives. Officials also use the lure of China's enormous potential market as leverage to encourage technology transfer and R&D investment from abroad. As a result, most of the world's leading computer and telecom companies have R&D investments in China.

- In the computer and telecommunications sector, foreign investors have established over 200 R&D centers, programs, or labs in China between 1990 and 2002. The number of newly established centers accelerated in the late 1990s but appears to have declined in the past two years. Chinese press reports estimate the overall number of foreign R&D centers in China to be anywhere between 120 and 400.

- Chinese high-tech enterprises are focusing their efforts on developing new high-tech standards for application in the China market and globally. These efforts have been aided by R&D investments and related systems and standards integration work that took place during the mid- to late-1990s and likely conveyed to Chinese partners—and potential future competitors—a good deal of technological know-how that local enterprises probably would not have had access to otherwise or been able to develop independently.

- On balance, although foreign R&D centers are contributing to China's impressive recent high-tech growth and increasing competitiveness in ICT industries, they are contributing as much or more—under newly consolidated, wholly foreign-owned R&D enterprises—to foreign companies' high-tech development and production capabilities and, thus, to the US economy.

- Efforts are needed to develop a means of collecting data on global R&D activities in order to provide policymakers and business executives with a clearer, more comprehensive, and timely picture of R&D investments abroad. Statistical analysis currently underway in the United States should be coordinated with data collection efforts in other countries, and new statistical methods implemented as soon as possible.

- Information exchanges on high-tech R&D activities should be added to the agenda of meetings held under the US-China S&T Cooperation Agreement. Current Chinese interest in analyzing and quantifying the growing global R&D trend, along with ongoing cooperation by the US and Chinese National Science Foundations on standardizing collection of statistical data, makes this an opportune time to initiate a bilateral effort to track international R&D investments in China.

- Reforms are needed to the US export control process to account for this new form of international high-tech trade. In the near-term, the US "deemed export" rule should be amended to cover advanced foreign R&D investments and technology transfers outside the United States. Over the longer-term, the US export control system should be reformed to provide a means of monitoring global R&D and other newly emerging international business dynamics. To achieve this objective, senior executive branch officials must make reforming the export control process a top priority and consult with both Congress and industry to develop a workable system.

- Although the United States benefits form a continued net inflow of R&D investment from around the world, US government funding for basic research and education should be increased in order to maintain the US lead in critical high-tech industries and innovation. This is crucial to ensuring the United States remains economically, technologically, and militarily competitive. Additionally, as foreign nationals working in US labs, universities, and high-tech companies become able to find similar work in their own economies due to globalization, the US government must invest more in grade school and secondary education, particularly in basic sciences, mathematics, and engineering, or risk falling behind.

— 1 —

Introduction

"The People's Republic of China is moving to become a global technological and scientific powerhouse."[1]

Few doubt that one of the most critical yet also most uncertain relationships to shape the 21st century will be that between the United States and the People's Republic of China (PRC). Whether this relationship between the world's sole remaining superpower and a rapidly emerging major regional power is, in strategic terms, cooperative or competitive will weigh heavily on international relations and the overall global balance of power for many years to come.

The question is this: can the world's leading nation, emboldened by unprecedented economic, military, and technological supremacy, accommodate a rival, emerging power center? History is not encouraging, particularly based on events over the last century. When major power struggles have emerged in the past, conflict often has been the outcome. Mindful of this legacy, leaders in the United States and the PRC have sought generally to ease tensions and to improve relations while keeping close tabs on the other's intentions and capabilities.

This carefully calibrated "hedge" approach that has dominated bilateral US-China relations since the end of the Cold War is unlikely to endure indefinitely. At some point, both countries will turn decisively in one direction or the other. By a number of measures, the year 2002 may be remembered as just such a turning point. The past year saw a swing toward a more conciliatory US-China relationship, with common interests in cooperation seeming to outweigh persistent mutual suspicion.

Among the more positive developments in US-China relations in 2002 was the establishment of permanent normal trade relations (PNTR) and the long-awaited entry of both the Mainland and Taiwan into the

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[1] Phyllis Yoshida Genther, "Asian economies striving to enhance innovation capabilities," *Research●Technology●Management*, vol. 44, no. 1 (January/February 2001), 2–6.

World Trade Organization (WTO).[2] This, perhaps more than any other development, helped create in the United States an air of optimism about China's future and of America's opportunity to share in the world's fastest-growing, most dynamic economy.

Also contributing to a more positive outlook for US-China relations was not, one but, two presidential summits held in 2002, the first hosted in Beijing in late February and the second in mid-October at the president's ranch in Crawford, Texas. While neither had an ambitious agenda nor resulted in any major new agreements, each summit was viewed as successful and contributed to the realization of a more "candid, constructive, and cooperative" bilateral relationship.[3] In between these two summit meetings, China's new leader, Hu Jintao, also made a much publicized and highly effective inaugural visit to the United States. Taking into account these and a series of other high-level exchanges—including events marking the 30th anniversary of President Nixon's historic opening to the PRC—the year ended as a relatively active and upbeat period for US-China diplomacy.

Underlying these generally positive developments, however, was a growing strain of anxiety evident on both sides of the Pacific over the long-term political, economic, and military intentions and capabilities of the other. Differences over Taiwan, proliferation concerns, missile defense plans, and a variety of other issues occasionally rose to the fore. But more pressing domestic affairs and multilateral concerns involving the international War on Terrorism, the run-up to conflict with Iraq, and North Korea's efforts to develop nuclear weapons soon overshadowed bilateral differences and offered new opportunities for cooperation.

It was in this context that another issue emerged that is likely to have substantial long-term implications for US-China relations as well as for the broader international economic and security environment. That is, the prospect has slowly begun to emerge that the PRC is becoming more

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[2] The PRC formally became a member of the WTO on December 11, 2001 and was granted PNTR status by the United States effective on January 1, 2002 under Public Law 106-286. For an overview and chronology of US-China relations in 2002, see Kerry Dumbaugh, *China-US Relations: Issue Brief for Congress*, IB98018 (updated January 31, 2003), available online at http://fpc.state.gov/documents/organization/17320.pdf.

[3] Although George W. Bush came into office viewing the PRC as a "strategic competitor," the administration has since shifted course and now seeks a less-confrontational relationship with China. This policy was reiterated most recently in congressional testimony by Deputy Assistant Secretary of State Schriver, despite growing anxiety on the part of US officials who view China's position on the war with Iraq and North Korean nuclear crisis as less than cooperative. See Randall G. Schriver, "The Effects and Consequences of an Emerging China," Testimony Before the Subcommittee on East Asia and the Pacific, Senate Foreign Relations Committee (March 19, 2003).

competitive in a number of important high-tech areas, far sooner than most would have predicted. The now steady flow of news reports heralding China's growing high-tech prowess in computer electronics, semiconductors, and telecommunications prompted the following question on the cover of *BusinessWeek* magazine in October 2002:

High Tech in China: Is It a Threat to Silicon Valley?

While a deliberately provocative headline, the question is one that industry experts are beginning to ask more and more. But what has prompted this growing concern?

The emergence in China of high-tech competitors, in and of itself, should be neither surprising nor troubling. An economy as large as China's—supplied by an enormous population containing many well-educated, talented, and increasingly skilled men and women—will inevitably climb the technological ladder and begin producing and exporting more high-tech goods. This is to be expected and, undoubtedly, will create additional opportunities for foreign investors.

Rather, what has surprised many observers is the pace at which the PRC is achieving its aim of becoming more domestically and internationally competitive in a number of critical high-tech industries. One indicator of this is China's growing trade in high-tech goods, which made up approximately 20 percent of the PRC's manufactured exports in the year 2000.[4] While this might not seem too extraordinary a number, it is impressive when compared to China's level of high-tech exports a mere decade ago, when only about five percent of China's exports were classified as high-tech.

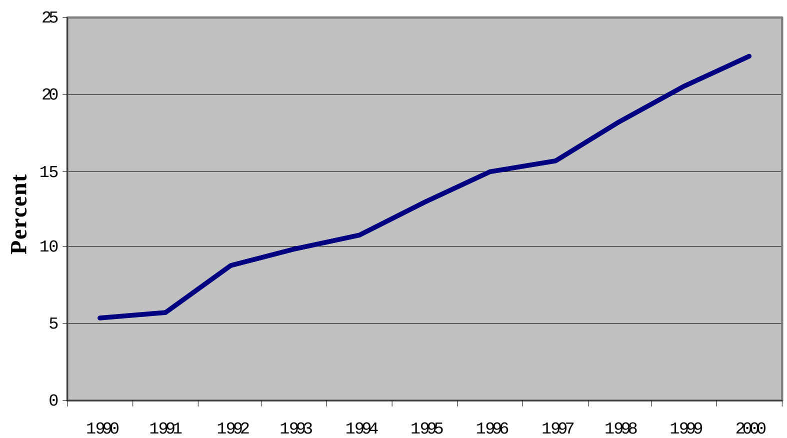
Another more revealing statistic is the extent to which China's high-tech exports are the product of foreign-invested enterprises. In 1995, the latter accounted for as much as 80 percent of China's overall exports in such capital- and technology-intensive industries as electronics and

[4] Data compiled by the World Bank show China's high-tech exports to be 18.6 percent of overall trade in 2000. See The World Bank Group, "China Data Profile," *World Development Indicators* database (April 2002). Using UNCTAD data, the percentage of high-tech PRC exports was 22 percent of total exports for the year 2000. High-tech manufactures are defined, in this case, using Standard International Trade Classification (SITC) codes. For that latter study, high-tech manufactures include the following SITC codes: 524, 541, 712, 716, 718, 751, 752, 759, 761, 764, 771, 774, 776, 778, 792, 871, 874, and 881.

electrical appliances. By the year 2000, this number had dropped to about 50 percent.[5]

As the above indicators demonstrate, China is making steady progress in advancing its industrial and technological capabilities. At the same time, however, the data also reflect China's continued dependence on foreign inputs. As a result, it is difficult to judge China's technological trajectory. Will the PRC become a true high-tech competitor (independent of foreign technology and know-how) or, as many would argue, is China's growing high-tech trade dependent almost entirely on foreign investment (which presumably could be withheld)? The answer to this question is important not only in terms of US economic interests, but also for long-term national and regional security considerations.

Figure 1: PRC High-Tech Manufactured Exports as a Percentage of Overall Trade (1990-2000)



Source: United Nations Conference on Trade and Development (UNCTAD), *Science and Technology for Development Database*, 2002.

An important and growing trend that emerged in the 1990s—and is the focus of this report—might shed some light on China's technological future. As discussed in Chapter Two, the current wave of economic globalization has fostered interesting new patterns of international trade and cross-border flows of labor, capital, technology, and know-how. In particular, the 1990s witnessed a rapid increase in the level of research

[5] Yasheng Huang, *Selling China: Foreign Direct Investment in the Reform Era* (New York, NY: Cambridge University Press, 2003).

and development (R&D) investment and collaboration conducted overseas, particularly in high-tech industries such as electronics and computer software. By mid-decade, this phenomenon had spread to the developing world. China, which has recently overtaken the United States as the most preferred destination for foreign investment, has benefited more than most from the internationalization of high-tech R&D.[6] Today, many of the world's leading high-tech firms have established some type of R&D program or center in the PRC.

Why is this significant? The influx of foreign scientific and technological know-how and equipment that is integral to conducting high-tech R&D could serve as an important accelerant in China's plans to modernize its economy, industry, and military. The best evidence of this is the United States. Following the end of World War II, the US government made a critical decision to continue pouring large sums of money into fundamental or "pure" scientific research, the results of which would later become the engine for unprecedented economic growth in the years and decades following the war. These policies were motivated by US leaders' wartime experience, when scientific and technological (S&T) capabilities (particularly, atomic weaponry) proved decisive in winning the war.

Once hostilities ceased, however, the US commitment to advanced S&T development did not. In a landmark study published just prior to the end of the war, one of the United States' leading thinkers and director of the wartime Office of Scientific Research and Development—Vannevar Bush—recommended to President Truman that the United States continue in peacetime to support large-scale government funding of "frontier" scientific research.[7] Much of America's post-war dominance in terms of economic, industrial, technological, and military

[6] A.T. Kearney, *FDI Confidence Index 2002* (Alexandria, VA: Global Business Policy Council, September 2002), 24–25.

[7] Prior to the war, very little public funding was available to scientists and researchers. This changed with the onset of conflict. The Office of Scientific Research and Development, a civilian agency, was established as an emergency measure in 1941 to oversee and coordinate the nation's weapons development efforts, including the Manhattan Project. After the war, continued public funding of scientific research was intended to support innovation as well as "pure" science with no immediately apparent practical application. Among other things, the Bush Report promoted enhanced government-university S&T collaboration and recommended the creation of a "National Research Foundation," the institutional predecessor to today's National Science Foundation (NSF). See Vannevar Bush, *Science — The Endless Frontier: A Report to the President on a Program for Postwar Scientific Research* (Washington, DC: US Government Printing Office, 1945). For a discussion of the history and legacy of wartime S&T decision making, see Stanley Goldberg, "Big Science: Atomic Bomb Research and The Beginnings of High Energy Physics," Speech before the History of Science Society (1995), available online at http://hssonline.org/teach_res/hst/mf_hst.html.

capabilities can be traced back to this decision to invest public funds in basic scientific development.

Having witnessed America's success, other countries, including the PRC, are following suit. In this context, the potential benefit to China of hosting foreign-sponsored, high-tech R&D is obvious. What is only now becoming apparent is the incentive for companies (and countries) to conduct R&D abroad, which is tied directly to the current wave of globalization, as outlined in Chapter Two.

In order to determine how an in-flow of advanced R&D might impact China's development, it is critical to examine how well the PRC is able to absorb the scientific and technological know-how that accompanies foreign R&D investments. This ability will depend on the PRC's own S&T infrastructure, strategies for development, and capacity to exploit these assets. Chapter Three addresses this question by reviewing China's efforts to overhaul its S&T system over the last two decades in parallel with the country's more renowned market-oriented economic reforms. These dual efforts are ongoing and are being influenced by exposure to foreign R&D practices.

Chapter Four gets to the heart of the matter: the emergence and evolution of foreign-funded high-tech R&D in China and its implications for China's technological development. The discussion focuses on two critical high-tech industries that are highly dependent on R&D and are increasingly international in scope: the computer and telecommunications industries. As the chapter recounts, the trend toward foreign R&D has evolved rapidly and in line with international trade dynamics. This observation holds important implications for China's future scientific, technological, industrial, political, and military capabilities and will impact, therefore, China's role in the region and relations with the United States and other major powers.

The report concludes by assessing the risks and rewards for China and the United States as well as the changing nature of US-China relations as the PRC becomes a more formidable high-tech competitor. Is this, from the American perspective, a serious and destabilizing concern, or can the US and global economy accommodate growing numbers of not only low-tech manufactures bearing the "made in China" label, but also much more sophisticated, high-tech wonders as well? Will the rewards of high-tech collaboration outweigh the potential risks? Is there any reason to believe that foreign-invested R&D in China will contribute to the PRC's military modernization plans, and would that be problematic vis-à-vis US and allied military transformation?

How these questions are addressed will have long-term and far-reaching repercussions, particularly if anxieties about China's industrial and technological modernization are handled badly. The example of US-Japan relations, which deteriorated remarkably over trade disputes during the 1980s, does not augur well for future US-China relations as the economy on the Mainland expands into new high-tech sectors. In order to avoid the excesses of the 1980s, which in the end undermined both US and Japanese interests, it is important to understand the reasons underlying China's high-tech emergence and the role played by US and foreign investment in this development. This report examines one critical aspect and contributor to this trend.

TERMINOLOGY

Throughout this report, the terms "science and technology" as well as "research and development" are used repeatedly. It is important, therefore, to understand at the outset how these terms are defined.

Science and Technology (S&T)

Simply put, science is the pursuit of an informed understanding of the world around us.[8] In other words, science helps us comprehend the most fundamental, observable phenomena, such as how clouds form, what makes thunder, and why the sky is blue. To explore the answers to these questions in a disciplined and measurable way is to conduct science. Technology is often used in this pursuit, that is, as a means of manipulating the surrounding environment in order to conduct experiments, perform a particular function, or achieve some other intelligent objective. To put it another way, science and technology are the most basic tools of modernization and are a useful measure of how advanced a society is and may become over time.

Another important distinction is that while scientific progress requires technology, technological innovation does not necessarily require science. Although it certainly does help to comprehend the scientific principles underlying a particular technology, it is possible to adapt and even improve upon existing technology without fully understanding it (though presumably significant technological progress would be seriously impeded by the lack of such basic comprehension). For example, today one can plug in a table lamp with a reasonable

[8] Much of the discussion on science and technology is based on observations contained in an essay by Stanley Goldberg, "Big Science: Atomic Bomb Research and The Beginnings of High Energy Physics" (1995).

expectation that it will give off light without having to first gain a working knowledge of the principles of electricity. In this way, technology can either be the means or merely the result of scientific investigation. For this reason, it is important in analyzing technological competence to include both the fundamental scientific capacity of a state (essentially the "know-how") as well as a nation's technological output (high-tech products or materials) to determine how advanced a country is and is likely to become.

Research and Development (R&D)

The definition of R&D is a more complicated affair given variations in terminology utilized in separate communities and in different parts of the world. Due to these variable taxonomies, international comparisons of R&D are broken down into three broad categories: basic research, applied research, and technological development. Generally, these terms refer to systematic research conducted to achieve one of three objectives: 1) the creative pursuit of knowledge to enhance overall human understanding (basic research); 2) research conducted to meet a particular purpose or need (applied research); or 3) research intended to lead to a practical or specific application, design, or process (technological development).[9] While commonly viewed as distinct activities requiring different approaches, inputs, and participants, these three types of research activities often overlap. And, though imperfect, cross-national comparisons of R&D that utilize these three general categories have proven useful and no more problematic than other suggested measures or terminology. Although the US and PRC definitions for these terms are worded using slightly different language, the meanings are generally the same (see Table 1).

Similar to the relationship between science and technology, it is important to recognize in assessing R&D that although these three types of research activities logically follow one another and represent a natural progression or "linear model of innovation," it is not essential that one activity follow the other.[10] Nor is it essential that individual competence

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[9] National Science Board, *Science and Engineering Indicators – 2002 (*Arlington, VA: National Science Foundation, 2002 (NSB-02-1), 4-10 (hereafter NSB, *S&EI—2002*). Chapter Four briefly notes the possible relevance of an alternative, slightly more complex model—the Stoke's matrix—to R&D in China. See fn. 19.

[10] The three-step, linear model of innovation can be traced back to Vannevar Bush, the prominent American engineer during World War II who promoted enhanced government-university S&T collaboration, championed the creation of a National Science Foundation, and whose ideas inspired what would later become ARPANET and then the Internet and world wide web. See Vannevar Bush, *Science—The Endless Frontier: A Report to the President by Vannevar Bush, Director of the Office of Scientific Research and Development* (United States Government

be achieved in each area in order to move along this innovative path; what is most important is that the results are accessible and transferable. In practical terms, this means that a country might be able to develop high-tech goods without necessarily having mastered the fundamental science that underlies them. But, as with S&T, though some technological innovation might be possible, continued innovation becomes much less likely and limited over time if the fundamentals are lacking. Alternatively, a society that is able to develop new products with the aid of external inputs but also enjoys a substantial scientific infrastructure is much more likely to gain the capacity to exploit these technological inputs over the longer term. Thus, the concepts of R&D and S&T are integrally connected, and the nature of this relationship must be examined within the societal, economic, and even political contexts of each nation state.

What is High-Tech?

One final word on terminology is needed, which concerns the term "high-tech." Although only certain products and industries are classified as high-tech, this is an inexact science and to some extent rests in the eye of the beholder. Moreover, any definition of high-tech requires periodic review given its impermanent nature; just as something is considered modern only for a time, so, too, is it considered high-tech. Another complication is that not all aspects of a particular industry, sector, or good are truly high-tech, leaving open to interpretation and judgment whether the entirety should be labeled as such. As a result, it is left to both industry and government to devise an appropriate, agreed-upon definition of what is, at any point in time, considered "high-tech."

Since this study focuses primarily on the computer electronics and telecommunications industries, the definition of high-tech adopted here is the one applied by the American Electronics Association (AeA). According to the AeA, industry sectors considered high-tech are simply those "in the business of making or creating technology products or services."[11] The AeA identifies nearly 50 high-tech industry sectors—

Printing Office, Washington: 1945), and "As We May Think," *The Atlantic Monthly*, vol. 176, no. 1 (July, 1945), 101–108. For a thoughtful, though brief, discussion on the use of these three terms and other possible alternatives, see NSF, *S&EI—2002*, 4-50.

[11] See American Electronics Association, "AeA Announces New High-Tech Definition" (February 25, 2002). The Organization for Economic Co-operation and Development (OECD) also classifies these and other "science-based industries whose products involve above-average levels of R&D" as high-tech. The NSF has adopted this definition in tabulating its figures for international R&D, noting, "no single preferred methodology exists for identifying high-technology industries, but most calculations rely on a comparison of R&D intensities"—

including computer software, hardware, and telecommunications services and equipment—as classified under a revised, six-digit coding method known as the North American Industrial Classification System (NAICS).

The NAICS, a system adopted by the US government in 1997 and by the AeA in 2002, is used across the United States, Canada, and Mexico to analyze economic activity. Unlike the system it replaced (the Standard Industrial Classification or SIC), the NAICS focuses on classifying industries and companies by how goods are produced rather than on the end product itself.[12] This is an important distinction that takes into account the fact that high-tech goods produced in some newly industrializing and developing states do not necessarily demonstrate advances in indigenous high-tech capabilities but, rather, are in many cases the result of foreign high-tech manufacturing processes or assembly lines re-located abroad. By focusing instead on the process by which a company or industry develops products or services, the system more closely captures the origins of today's high-tech and global trade dynamics.[13]

Not surprisingly, the shift in the NAICS' focus toward production processes has necessitated revisions and additions to the list, which was last reviewed in 2002. Among the sectors and items recently added to the "high-tech" category were fiber optic cable manufacturing, satellite telecommunications, industrial design services, computer training, Internet service providers, and web search portals. Most relevant to this study was the addition to the high-tech list of "R&D in physical, engineering, and life sciences," as well as "testing laboratories" (see Figure 2 for definitions of these terms).

Although the NAICS codes are used across North America, international data on economic activity and trade are collected mainly using other industry classification systems. The World Customs

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in this case, as calculated by the OECD. See NSB, *S&EI—2002*, 6-5.

[12] In the transition from the SIC to the NAICS, an entirely new industry sub-sector was added for "information services" (code 51), comprising 34 related industries. See US Department of the Census, "New Sectors in the NAICS" (updated March 1998), available online at http://www.census.gov/epcd/www/naicsect.htm#Information; and American Electronics Association, "Defining the High-Tech Industry: AeA's New NAICS-based Industry Definition" (February 2003), 3.

[13] This is not to say that the new statistical method represents an improvement in all instances. Of concern to this study is the fact that outsourced R&D expenditures under the NAICS system are counted under the primary enterprises' industry sector regardless of whether the actual R&D activity appropriately falls under this category. This observation is included in materials made available from the National Academy of Sciences in preparation for a "Workshop on R&D Data Needs" (April 7, 2003), specifically Mike Gallaher and Jeffrey Petrusa's, "Technical Memorandum on Service Sector R&D," RTI International, RTI Project No. 08236.002 (March 28, 2003), 13–14.

Organization has adopted a Harmonized System (HS) to track global trade, and the United Nations applies the Standard International Trade Classification (SITC) code.[14] The latter was developed specifically to aid in tracking cross-border transactions. Each system, while using different specific definitions and levels of classification, can be cross-referenced (though doing so can be arduous). The point here is that although each country and each classification system might define "high-tech" somewhat differently, these terms are becoming more uniform internationally due to inter-governmental and organizational efforts at standardization. As a result, what is considered "high-tech" in the US market is much the same today as that in any other developed or developing country.[15]

METHODOLOGY

The approach adopted in conducting this study was three-fold. Primarily, the information and conclusions put forth in this report are the product of insights gleaned through over three dozen interviews conducted in the PRC and Hong Kong in 2002 with industry representatives in the computer and telecom sectors, government officials, academics, and journalists. Nearly half of these conversations were with representatives of leading multinational, mainly US, high-tech firms with R&D programs in China or with Chinese enterprises involved in high-tech collaborations with foreign companies. The latter included a leading Chinese corporation as well as start-up enterprises.

The author conducted these interviews during two extensive trips to China in the summer and fall of 2002. Given the apparent consolidation of R&D centers in recent years, emphasis was placed on cities with the highest concentration of foreign-R&D centers, mainly those located

[14] The HS code classifies industries by four- and six-digit numbers. Using this system as a foundation, the United States utilizes a more detailed (i.e., eight- and ten-digit) version of this list—the Harmonized Tariff Schedule (HTS)—to track imports and the so-called Schedule B list to collect data on exports. Since most countries apply at least the HS' six-digit system to track imports and exports, analysts and officials are able to conduct cross-national comparisons. For an instructive discussion of the use of these different coding systems and their application to the computer software industry, see Pat Johnson, "Industry And Trade Classification Systems Used In the United States For The Software Sector (Washington, DC: US Department of Commerce, Software Technologies Division, August 2000).

[15] China, too, is struggling to define "high-tech." Presently, Chinese statistics use the OECD's definitions and classifications, which classify computer and office equipment as well as electronics and telecommunications equipment as "high-tech." This point is made in Rongping Mu, "Methodology for Evaluating International Competitiveness of High-Tech Industries," in *R&D and the Knowledge-Based Society: Linking the Production, Dissemination, and Application of Research*, Proceedings of the First Sino-US Science Policy Seminar, October 24-27, 1999 (Beijing: Science Press, 2000).

along China's eastern coast.[16] Due to the sensitivity of the issues involved, these discussions were conducted on a not-for-attribution basis. While no formal survey or questionnaire was used, the author generally asked the same set of questions of each subject. For the most part, the foreign executives interviewed were senior R&D managers.

In addition, the author conducted a number of interviews in the United States with experts on various aspects of trade and investment in, or security relations with, the PRC. These interviews supplemented extensive research conducted over the course of the project. This included detailed collection of data on commercial R&D programs established in China between 1990 and 2002 by US and other foreign commercial enterprises in the two industry sectors analyzed. Where possible, the latter information was confirmed by company representatives via telephone, fax, or email inquiries. To place this data in a theoretical context, the author reviewed the relevant literature on modern global trade theory; technology transfer models, mechanisms, and patterns; strategies of economic and S&T development; as well as management concepts related to R&D in high-tech industries. There has been a notable increase in the quantity of research studies and analyses on these issues over the last few years, providing a much richer and more robust collection of studies on what are fast-developing, global trends.

The third element of the methodology for this study was a vetting of interim findings and overall conclusions by experts in the field. First, the author presented preliminary findings before an audience of PRC industry and academic experts in Shanghai, China. This meeting occurred roughly halfway through the term of the study and at the end of the second research trip, thereby aiding the author's preliminary evaluation of data and insights gained to that point. More importantly, the meeting provided some confidence that, based on the positive response to the briefing by those in the field (including Chinese experts and foreign expatriates), the author had, for the most part, "got it right." Several months later, near the end of the study period, the author again presented interim findings, this time before a select assembly of Washington-area experts on US-China and global trade. Through these briefings, extensive feedback was provided on both broad and detailed aspects of the study, which benefited greatly from the reviewers' wide range of experience and expertise.

[16] The author made two visits each to Beijing, Shanghai, and Hong Kong, plus additional side visits to the cities of Hangzhou and Shenzhen.

While the methodology employed in conducting this study emphasized primary-source material gained through in-depth, in-the-field interviews, these observations and insights, inevitably, can offer only a snapshot in time. Supplementing these findings, however, are the author's own research and analysis of US commercial technology transfers to China conducted in 1997–98 (among the first research efforts to identify foreign high-tech R&D in China as an important emerging trend), which provides additional historical context and a first-hand understanding of the evolution of this trend. As a result, it is hoped that this report offers the reader additional perspective on high-tech R&D in China by contrasting characteristics of foreign R&D investments in the late 1990s with current developments, which should also enhance the report's long-term value. Nevertheless, the data and conclusions provided here are likely to soon be out of date due to the extraordinarily rapid pace of economic growth in China and the dynamism of the high-tech fields studied. Thus, this report's objective is to provide as comprehensive an analysis as possible of a growing trend that deserves continued close attention by US analysts, while acknowledging that these findings will not be the final word.

Lastly, perhaps because it is a relatively new and rapidly developing trend, the rise of foreign-sponsored high-tech R&D programs in the PRC has received only limited scholarly attention to date. This is unfortunate and likely reflects a characteristic divide in American studies of China, which tend to focus on either political-military and security concerns or economic and trade matters. Yet, a cross-cutting approach to the study of China (and other complex subjects) has become essential to understanding the synergistic influences and effects of an increasingly global environment. This study is an attempt to do just that, with the caveat that the author is an international security analyst and neither an economist nor a trade specialist. Nevertheless, the report seeks to incorporate these different perspectives and to reach an informed and balanced determination of where US interests lie with regard to outsourcing R&D to China and the implications of the possible near-term emergence of the PRC as a high-tech competitor.

Figure 2: Definition of High-Tech Industry R&D

R&D and Testing Labs

"These industries are key in creating new technologies." — AeA

Research & Development in the Physical, Engineering, & Life Sciences (NAICS code 541710). "This industry comprises establishments primarily engaged in conducting research and experimental development in the physical, engineering, and life sciences, such as agriculture, electronics, environmental, biology, botany, biotechnology, computers, chemistry, food, fisheries, forests, geology, health, mathematics, medicine, oceanography, pharmacy, physics, veterinary, and other allied subjects." (NAICS 2002)

Relevant sections include:

- Computer and related hardware research and development laboratories or services
- Electronic research and development laboratories or services
- Engineering research and development laboratories or services
- Industrial research and development laboratories or services
- Observatories, research institutions
- Physical science research and development laboratories or services
- Physics research and development laboratories or services

Testing Laboratories (NAICS code 541380). "This industry comprises establishments primarily engaged in performing physical, chemical, and other analytical testing services, such as acoustics or vibration testing, assaying, biological testing (except medical and veterinary), calibration testing, electrical and electronic testing, geotechnical testing, mechanical testing, nondestructive testing, or thermal testing. The testing may occur in a laboratory or on-site." (NAICS 2002)

Relevant sections include:

- Calibration and certification testing laboratories or services
- Electrical testing laboratories or services
- Electronic testing laboratories or services
- Industrial testing laboratories or services
- Laboratory testing (except medical, veterinary) services
- Mechanical testing laboratories or services
- Non-destructive testing laboratories or services
- Product testing laboratories or services
- Testing laboratories (except medical, veterinary)

Sources: North American Industry Classification System Definitions, 2002; American Electronics Association, *Defining The High-Tech Industry: AeA's New NAICS-based Industry Definition (*February 2003), 9.

Table 1: US and PRC Definitions of Types of R&D

TYPES OF R&D	US DEFINITIONS[*]	PRC DEFINITIONS[+]
Basic Research *Also: "fundamental," "pure," or "frontier" research*	"The objective of basic research is to gain more comprehensive knowledge or understanding of the subject under study without specific applications in mind. In industry, basic research is defined as research that advances scientific knowledge but does not have specific immediate commercial objectives, although it may be in fields of present or potential commercial interest."	"Basic Research is experimental or theoretical work undertaken primarily to acquire new knowledge without any particular application or use in view"
Applied Research	"Applied research is aimed at gaining the knowledge or understanding to meet a specific, recognized need. In industry, applied research includes investigations oriented to discovering new scientific knowledge that has specific commercial objectives with respect to products, processes, or services."	"Applied Research is original investigation directed primarily towards a specific practical aim or objective"
Development *Also: "experimental development" "technology development"*	"Development is the systematic use of the knowledge or understanding gained from research directed toward the production of useful materials, devices, systems, or methods, including the design and development of prototypes and processes."	"Experimental Development is systematic work, drawing on existing knowledge gained from research and/or practical experience, that is directed to producing new materials, installing new processes, systems and services, or improving current technology"

[*] Source: National Science Board, *Science and Engineering Indicators – 2002.* Arlington, VA: National Science Foundation, 2002 (NSB-02-1), p. 4-10. These definitions have been in use for several decades and accord with international usage.
[+] Source: Deh-I Hsiung, "An Evaluation of China's Science & Technology System and its Impact on the Research Community," *A Special Report for the Environment, Science & Technology Section*, US Embassy, Beijing, "Appendix I: Definitions of China's R&D Terminology" (Summer 2002). Definitions are used by China's National Bureau of Statistics and other state ministries and commissions.

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Globalization and High-Tech R&D

"...scientific research may be the most global of human activities..."[1]

If one were asked to characterize world affairs in the late 20th century, "globalization" would be for many the first word that comes to mind. Much has been written about this ongoing phenomenon, particularly over the last decade, and bitter debates continue to rage over its positive or negative effects on political, social, and economic progress. But what exactly does globalization mean, and how has it affected the conduct of high-tech R&D in the United States, China, and elsewhere?

First, it is important to note that many economic scholars would argue that globalization is not a new phenomenon at all, but an ancient one dating back to the first days of long-distance trade, exploration, and conquest. All of these activities, economists argue, brought new ideas, cultural influences, goods, and technologies to distant lands, where they were assimilated and adapted to fit local conditions and tastes, much as happens in today's world. For a theoretical construct, economists point to no less than the father of modern economics, Adam Smith, as having foreseen globalization as a natural extension of his "invisible hand" theory of capitalism outlined in *The Wealth of Nations*.[2] However, this view of globalization interprets the phenomenon more as an effect than as a driver of long-distance trade as well as economic and technological transformation, which is how most would characterize the concept today.

This more deliberate, driving aspect of globalization in the modern era is evident in the Merriam-Webster Dictionary's definition. It notes that globalization derives from the verb "to globalize," meaning: "[T]o make global; especially: to make worldwide in scope or application."

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[1] Statement attributed to participant John McTague, see National Science Foundation Tokyo Regional Office, "R&D and the Knowledge-Based Society: Proceedings of the October 1999 Sino-US Science Policy Seminar," *Report Memorandum* No. 00-01 (January 4, 2000), 249 and elsewhere.

[2] See, for instance, Jeffrey D. Sachs, "Globalization and the Rule of Law," speech before the Yale Law School (October 16, 1998), text available online at http://www.law.yale.edu/outside/html/Publications/pub-sachs.htm.

According to this definition, the term dates back to the 1940s, coinciding with what others have identified as one of several "waves" of globalization. Although an accurate description reflecting both the universal and active elements of globalization, this definition remains too broad to encapsulate the phenomenon that has more recently captured the world's attention.

More useful is the aforementioned "wave" approach to defining globalization. This model is adopted in World Bank analyses, which suggest the phenomenon originated in the 1870s when international flows of capital, labor, and merchandise first began to converge and to grow at a noticeably rapid pace.[3] Reforms leading to more liberal trade policies and technological advances were also essential catalysts for this first and two subsequent "waves" of globalization. The second wave is defined as the years following World War II (1945–80), while the third and current wave is identified as beginning in the early 1980s. Based on this analysis, what distinguishes the latter wave is a rapid rise in manufactured exports emanating from developing countries with high GDP growth rates (including the PRC).[4] In addition, enhanced training and educational opportunities for workers in developing economies as well as improvements in infrastructure have helped to fuel this wave of international trade in more advanced commodities. But what accounts for these new opportunities and technological advances? There would seem still to be more to the current wave of globalization than merely another period of rising international trade, investment, and growth rates.

Indeed, what arguably sets the current phase of globalization apart from earlier periods is today's near-universal and almost instant dissemination of information, technology, and know-how that is a driving force in *every* country's economy.[5] The information and

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[3] This section draws from analysis of the impact of globalization on the developing world in *2002 World Development Indicators* (Washington, DC: The World Bank Group, 2002), 325–331, as well as the World Bank, "The New Wave of Globalization and Its Economic Effects," Chapter One, in *Globalization, Growth, and Poverty: Building an Inclusive World Economy* (Washington, DC: The World Bank and Oxford University Press, 2002), 23–52. Also see related briefing by Paul Collier on "Three Waves of Globalization," available online at http://www.worldbank.org/research/global/slides/PRR/slide2.htm.

[4] World Bank reports find the growth in manufactured goods as a percent of GDP in low-income developing countries has risen in all regions of the world and today comprises over 80 percent of these states' exports (up from just 25 percent in 1980). *2002 World Development Indicators*, 325.

[5] This is generally the consensus reached by an international panel on globalization, which concluded: "…the current phase of globalization is fundamentally different from any other age in history, especially as a result of qualitative changes brought about by the speed of communication and the ease of access to information." United Nations, *Report on the 56th session of the United Nations General Assembly Second Committee High-Level Panel on Globalization and the State*, Conference Report (November 2, 2001), 1. The universality of this

communications revolution that sparked the high-tech boom of the 1990s (and the subsequent entrepreneurial and innovative "dot.com" frenzy) have so broken down traditional borders and barriers to trade that even the world's poorest nations now can access—in virtual if not physical form—much of the world's most advanced technological know-how, products, and processes.

What has made such unprecedented technological diffusion possible has been development of more sophisticated as well as steadily less expensive means of communication, transportation, and trade. For example, the charge levied for a three-minute telephone call from New York to London that today costs less than 75 cents would have cost the equivalent of $300 in 1930.[6] Conversations carried out over the Internet or via email can cost even less, if not be entirely free of charge. In similar fashion, travel has become far less time-consuming and relatively inexpensive. A round-the-world journey today requires just two days' time and considerably less expense by airliner than the weeks or months and vast sums of money needed to fund the transcontinental voyages of the past. Moreover, today's global market rewards companies able to deliver products "just in time," if not overnight or even instantaneously via electronic commerce. The result is that economic and technological development today depends less on where one resides than on how well connected and ultimately how intelligent, responsive, innovative, and inventive one can be. It is this increasingly transnational nature of scientific and technological capacity that is the critical distinguishing feature of the current wave of globalization.

A growing indicator and important effect of this new transnational technological environment is the rise in overseas research and development. Until fairly recently, the vast majority of R&D work conducted by American high-tech firms was performed within US borders or, in select cases, in allied nations abroad, primarily Great Britain, Germany, and Japan. The same held true for most other Western nations, whose industrial R&D activities were concentrated at home or, if abroad, frequently were located in the United States. Beginning with the

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phenomenon is reflected, as well, in attempts to measure and rank the level of globalization of each nation-state. See A.T. Kearney/Foreign Policy Magazine, "Measuring Globalization," *Foreign Policy* (January-February 2001). This "Globalization Index" ranks each states' rate of globalization by measuring trade in goods and services, financial transactions, interpersonal interactions, cross-border flows, and technology. In the past two years, the Republic of Ireland has replaced Singapore as the most globalized state.

[6] This example (using year 2000 dollars) is taken from Medard Gabel and Henry Bruner, *Global Inc.: An Atlas of the Multinational Corporation* (New York, NY: The New Press, October 2002).

latest wave of globalization and accelerating in the 1990s, however, a growing number of multinational firms have begun to explore opportunities to expand and outsource R&D work to the developing world. While still making up only a small fraction of overall industrial R&D, the emergence of high-tech R&D investment in far corners of the world represents a new global dynamic that will have substantial and long-term economic impact as well as political, social, and security implications.[7]

THE RISE OF GLOBAL R&D

There are numerous factors driving the increasing internationalization of corporate R&D. The advent of information communications technology (particularly the Internet) is the most obvious, but by no means the only catalyst behind this new trend.

Another important driving factor toward more global R&D is the way technological advances are realized in the information and communications industries, which relies as much on manufacturing technology as on services. That is, sustained growth in these industries requires not only equipment support and hardware improvements, but a continuous cycle of innovation accompanied by extensive intellectual support services. Imagine, for example, buying a new laptop computer for the first time and having no help line to consult when the computer inevitably freezes up or reports a total "system failure." The growth in computer and other service-reliant industries has led to a corresponding increase in the level of services-based R&D, which now accounts for as much as 20 percent of overall industrial R&D in the United States.[8] Furthermore, services-based R&D—namely contract, retail, transport, and other support-related services—is in many ways more portable than manufacturing-based R&D; the latter is generally more closely tied physically, geographically, or intellectually to a particular location. As a result, corporations are more likely to shift services-based R&D activities abroad and are doing so in growing numbers.

Multinational firms, in fact, are playing a central role in the internationalization of high-tech R&D. This is due to a widespread change in the source of funding for most R&D activities: today, industry

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[7] Fully two-thirds of US R&D conducted overseas in 1998 was concentrated in Canada, France, Germany, Japan, and the United Kingdom (all US allies). Japan is the largest foreign R&D investor in the United States, followed by Germany and the United Kingdom. NSB, *S&EI—2002*, 4-60.

[8] NSB, *S&EI—2002*, 4-52/3, citing 1997 figures.

investment far outpaces government funding for R&D. In the United States, this shift first emerged after 1980, as the latest wave of globalization was just getting under way. It was then that, for the first time, private-sector industry expenditures on R&D matched federal outlays, and from there industry-invested R&D has increased steadily. By the turn of the century, US industry was funding more than two-thirds of all domestic R&D and performing nearly three-quarters of this work, while the share of government-funded R&D has declined across the board.[9] Over the past decade, a similar trend has emerged in many other Western economies.[10] It is not surprising, then, that as industry became the primary source of R&D funding, more of this investment and activity began to flow overseas, where MNCs are seeking to exploit new markets throughout the developing world.

As in earlier waves of globalization, overseas R&D is also made easier by the enhanced mobility of both human beings and financial capital. Today, talented individuals and foreign investors face few international barriers in seeking innovative opportunities across the globe. In fact, these assets are likely to be drawn to wherever a supportive environment for technological innovation exists and is fostered over time.[11] For this reason, numerous countries are attempting to replicate the success of California's Silicon Valley by developing new high-tech development zones or "science parks" designed to attract researchers, entrepreneurs, and venture capitalists from around the world. For their part, high-tech firms often find that R&D conducted in foreign locales can inspire new ideas and uncover unique sources of innovation. Moreover, conducting R&D abroad can at least temporarily reduce labor costs where firms are able to tap into local, and increasingly high-skilled, labor in the developing world.[12]

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[9] By the year 2000, government-funded R&D as a share of US GDP had dropped to only 25 percent, the lowest level since the National Science Foundation began keeping records on R&D spending in 1953. Since 2000, the level of federal spending on R&D has risen two to three percent. Reported in Brandon Shackelford, "Slowing R&D Growth Expected in 2002," *National Science Foundation Issue Brief*, NSF 03-037 (December 2002).

[10] Russia is the exception, where government funding for R&D remains higher than industry investment. NSB, *S&EI—2002*, 4-7– 4-9 and 4-54.

[11] According to the NSF, more than half of all US R&D hails from only six states, centered along well-known high-tech corridors. Richard Bennof, "Half the Nation's R&D Concentrated in Six States," *InfoBrief* NSF-02-322 (Arlington, VA: National Science Foundation, Division of Science Resources Statistic, July 2002).

[12] Shahid Yusuf and Simon J. Evenett, *Can East Asia Compete?: Innovation for Global Markets* (Washington, DC: The World Bank and Oxford University Press, 2002), 56–58.

In turn, this growing, global dispersion of skilled engineers, scientists, and researchers—many of whom were trained in American universities—has helped promote the rise of international research consortia. Due in part to the decline in government funding for R&D, scientists from around the world are collaborating on tackling a number of difficult areas of fundamental and applied research, working together to more rapidly achieve a shared scientific objective.[13] Projects such as the international space station, Antarctic field research, Human Genome Project, and efforts to find a cure for HIV/AIDS, to name just a few, all have benefited from cooperative international R&D. Newly formed global technology alliances among corporate partners also are growing in number, with hundreds more created each year. These inter-firm projects are designed to accelerate commercial advances in fields such as pharmaceuticals and biotechnology, information communications, aerospace and defense, advanced materials, and the automotive industry.[14] Increasingly, scientists and researchers from less-developed countries are participating in, and contributing to, these scientific and technically ambitious efforts.

Another factor driving global R&D is the extremely competitive nature of high-tech industries such as computer software development and wireless telecommunications. Increasingly, the race for product innovation has led multinational firms to seek the competitive advantage gained from round-the-clock R&D. Having researchers located across different international time zones that, as a team, are able to work continuously on a specific problem or project allows a virtual 24/7 development cycle. Once again, the information communications revolution has made this possible, allowing R&D to transcend both national borders and normal work-force limitations.

Finally, an important driver facilitating the globalization of R&D is the move toward normalization of international trade through the World Trade Organization (WTO). As more developing countries become members of this international forum, their economies will become substantially more attractive to foreign high-tech investors concerned with fair trade measures and effective enforcement of intellectual property rights. Even the expectation of China's pending membership in

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[13] From the 1950s through the 1970s, the US federal government funded most of the country's R&D, which was directed primarily at defense systems development, the space program, and alternative energy resources to help alleviate the energy crunch of the 1970s. Following the end of the Cold War, the United States and allied nations witnessed significant reductions in the level of government-funded R&D. NSB, *S&EI—2002*, 4-7.

[14] NSB, *S&EI—2002*, 4-39.

the WTO had a palpable effect on investor confidence, leading many high-tech corporations to expand their investments there long before China's entry into the WTO became official in December 2001.

If the factors and conditions outlined above persist, there is no reason not to expect further expansion of global R&D to continue at least over the near-term, if not considerably longer. With this in mind, the next section briefly explores how this trend has affected international trade and investment, in both the developed and developing world.

THE INFLUENCE OF GLOBAL R&D ON INDUSTRIALIZED AND DEVELOPING ECONOMIES

There are a variety of ways in which the trend toward more global R&D is impacting economic development strategies as well as national policymaking geared toward ensuring sustained economic growth. The impact of these changes is widespread and likely to be long-term.

The Impact of Global R&D on Economic Development

The rise in global R&D is reflected most clearly in increased levels of foreign funding as a major source of national R&D expenditures. While this is not the case everywhere—foreign-funded R&D accounts for no more than one percent of overall industrial R&D in some countries such as Japan (0.4 percent)—it represents a steadily growing share of overall R&D funding (between five and 25 percent) in many Western economies (see Figure 3). This trend is also evident in the United States, where the amount of foreign-funded R&D has quadrupled since the mid-1980s.[15]

Because most R&D abroad takes the form of a commercial enterprise or joint venture and thus remains squarely within the private-sector realm, this activity is not tracked comprehensively in either national or international statistics.[16] The lack of detailed data on these

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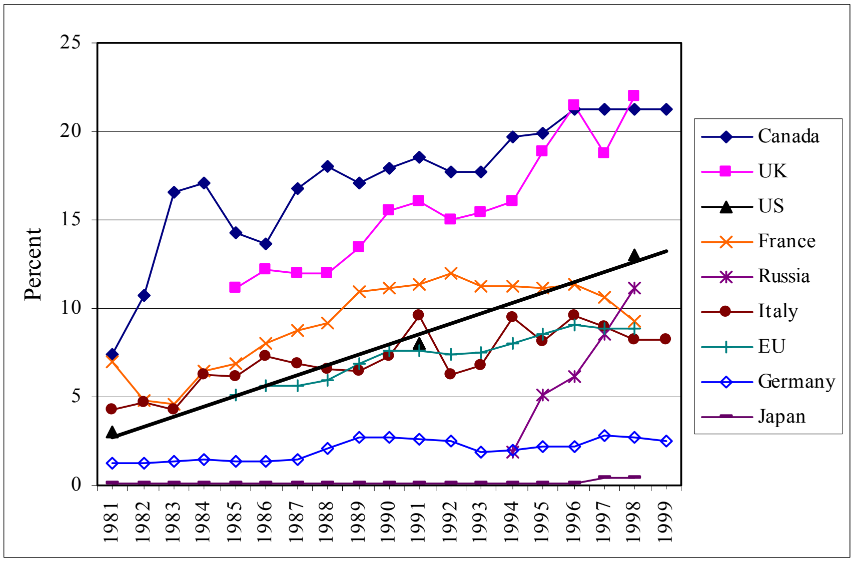
[15] Data provided by Donald Dalton, Bureau of Economic Analysis, US Department of Commerce, March 2003, updated from Donald H. Dalton, M.G. Shapiro and G. Yoshida, *Globalizing Industrial Research and Development* (Washington, DC: US Department of Commerce, Office of Technology Policy, 1999), 7.

[16] While quite a lot of data is available on annual corporate R&D expenditures (particularly through reports published by private research firms, business and industry magazines, as well as US and foreign government offices), these generally do not include, or break down, data for overseas R&D investments. A fair amount of information on corporate R&D abroad is available through annual corporate reports and press releases, market analyses, and investment-related disclosures, but not in any comprehensive manner. The best available comprehensive data to date is found in sources cited throughout this chapter (i.e., annual NSF reports and economic data compiled periodically by the Department of Commerce's Bureau of Economic Analysis and data

Figure 3: Foreign-Funded R&D as a Proportion of Industrial R&D



Source: NSB, *S&EI—2002*, 4-54 and Data Table 4-45. Note: US data represented as trend line.

activities is especially problematic with regard to US figures, whether on foreign-funded R&D in the United States or overseas R&D conducted by American corporations. The most comprehensive and best-available statistics derive from a 1998 US Department of Commerce survey. According to this study, there were a total of 715 foreign-funded R&D facilities located within US borders in 1998, the majority of which were either Japanese-owned subsidiaries or affiliates of German and British companies. At the same time, the survey counts just 186 US-owned R&D facilities located abroad, placing these primarily in Japan, Canada, and Western Europe.[17] Although the study remains an important and useful survey as an early attempt to document this very dynamic trend, the data contained in the report likely under-represent the true number of

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contained in studies by the Technology Administration's Office of Technology Policy). For the China market, the US-China Business Council provides regular but only brief information on many R&D-related investments in its "China Business" index listed in the back of each China Business Review. A number of academic and other studies are underway to better understand the global R&D trend, but none is comprehensive or definitive. Given these limited data sets, concerns over the lack of comprehensive international R&D-related data persist and have been voiced in studies by the National Science Board and the Council on Foreign Relations (e.g., Callan, B., S. S. Costigan, and K. Keller, *Exporting U.S. High Tech: Facts and Fiction about the Globalization of Industrial R&D* (New York, NY: Council on Foreign Relations, 1997), among others.

[17] Dalton, et al., 38.

R&D affiliates established in the United States or abroad. For one thing, the survey counts only a very small number of US-owned R&D facilities in the PRC (citing 11 facilities owned by eight different American firms) despite the report's recognition of this as a growing trend.[18]

In addition, the report identifies a number of other interesting trends evident in the US market and abroad:

- More than half of foreign-funded R&D invested in the United States is concentrated in three industries: pharmaceuticals, chemicals, and electronics.[19] These industries—plus automotive—also dominate US corporate R&D investments abroad.

- Although reasons differ across industry sectors, the survey identifies the main purpose for investing in R&D abroad (whether foreign R&D investment in the United States or by US firms investing abroad) is to acquire technology and/or to be near to an industry's innovative center in order to keep abreast of the latest technological developments. Other reasons include serving parent company interests or needs of the local-market, as well as access to foreign R&D labs and pools of highly skilled, low-cost labor.[20]

- Most foreign-funded R&D in the United States is clustered in a few areas on the West coast (Silicon Valley), the East coast (around Route 128 in Boston, Princeton University's environs in New Jersey, and North Carolina's Research Triangle), or areas surrounding major universities located across America's heartland (Michigan, Ohio, Illinois, and Texas).[21] The integrative model for high-tech development—i.e., the clustering

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[18] Ibid. 35–39. The report acknowledges that the data provided by the Commerce Department's Bureau of Economic Analysis does not account for R&D expenditures abroad that are invested outside the corporate structure (i.e., in university or other academic lab programs) or outside majority-owned ventures. The report's appendix includes a useful table of US-sponsored R&D programs abroad, including those in China and elsewhere. Based on the author's own research and experience, however, this data—even then—did not reflect the full extent of existing US-funded R&D programs established in the PRC.

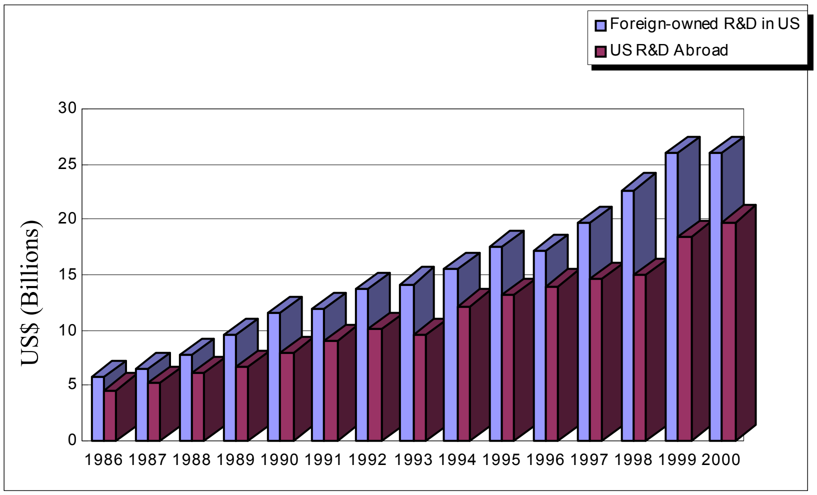
[19] Dalton, et al., 18.

[20] Ibid. 28–30.

[21] Ibid. 25.

of high-tech enterprises near leading universities and areas with technologically advanced infrastructures—utilized in these high-tech areas is being copied in many regions across the globe.

Figure 4: US R&D Flows—Incoming R&D Funding Outweighs Outflow



Sources: Bureau of Economic Analysis, US Department of Commerce, 2003; Dalton, et al., *Globalizing Industry Research and Development* (Washington, DC: US Department of Commerce, 1999).

- A rapid increase in foreign-funded R&D in the United States is complementing growth in US R&D investments abroad. In fact, US corporate R&D expenditures abroad increased four-fold between 1986 ($4.6 billion) and 2000 ($19.86 billion), outpacing the average rate of growth for US corporate R&D spending at home. The average percentage change in US R&D expenditures abroad (11%) outpaced US industry R&D domestic spending (8.6%) between 1994 and 2000.[22] That is not to say, however, that this activity is necessarily harmful to the US economy. Rather, the evidence viewed as a whole suggests otherwise. The outflow of US R&D dollars, for instance, was offset by the rise in overall foreign-funded R&D coming into the United States, which continues to exceed total US R&D investment abroad (see Figure 4). Moreover, as discussed in later chapters, a number of

[22] Ibid. 33; NSB, *S&EI—2002*, 4-9 and 4-18; and Bureau of Economic Analysis, US Department of Commerce, 2003.

additional tangible and intangible benefits often accrue from foreign investment and technology transfers that could make even a net outflow of R&D dollars advantageous. Nevertheless, the Commerce report notes that the "intensity of R&D globalization" (the ratio of overseas R&D relative to domestic R&D spending) in the United States had reached 13 percent by 1997 and hovered between 14 and 16 percent through 2000.[23] If continued over a long period of time and possibly without the accompanying benefits, this shift in R&D assets could prove worrisome down the road.

- The desired by-product of R&D—patents—also is becoming more global in scope. Just as R&D investments are growing in overseas markets, so are the numbers of foreign patent applications. This is true in the United States and for US patent applications abroad. Indeed, though US-owned patents still dominate the American market, foreign patents are growing at a faster pace, particularly in the information technology sector. At the time of the aforementioned Commerce study, South Korea and Taiwan had made impressive gains in patenting new technologies in the United States.[24]

- Finally, a key finding highlighted in the 1999 Commerce study is the trend toward more globally dispersed R&D. This conclusion is based on the increasing levels of foreign R&D investment appearing in distant areas across the developing world. The Commerce Department report was among the first to attempt to document this new dynamic. Of the nearly 200 US-owned R&D facilities abroad that the report identifies, almost one in ten was located in China, Mexico, India, Brazil, or Taiwan (see Figure 5).

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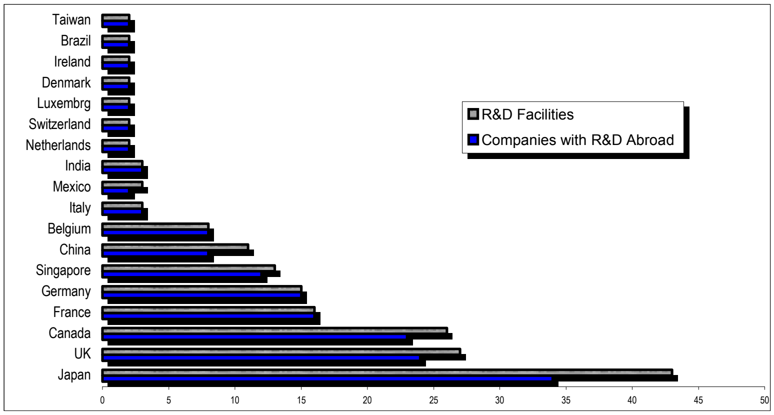
[23] Ibid. 36–37; and Bureau of Economic Analysis, US Department of Commerce, 2003.

[24] Ibid. 47–52.

Figure 5: US R&D Abroad (1997)



Source: Adapted from Dalton, et al., *Globalizing Industry R&D* (Washington, DC: US Department of Commerce, 1999), Table 11, 39.

The Impact of Global R&D on National S&T Policymaking

The primarily commercial-driven trends identified above are impacting national S&T development strategies in the United States, Europe, Asia, and elsewhere.[25] The most immediate implication of industry's growing share of R&D expenditures—which generally favor applied research and technology development efforts—is the need for increased government support of basic research. Funding for what is sometimes referred to as "frontier" research and development (beyond what is considered commercially viable R&D) is essential to ensure long-term scientific and technological development that, in turn, is needed to fuel sustained economic growth. The priority given to basic R&D funding is a common thread and key recommendation cited in a number of recently published studies on S&T trends and their implications for long-term US economic and security interests.[26] Similar priorities are reflected in the European Union's Fifth Framework Programme for Research and Technological Development (1998–2002) as well as in the recently announced Sixth Framework (2002–2006). Not

[25] Jerry Sheehan, OECD Science, *Technology and Industry Outlook 2002*, PowerPoint briefing (November 2002).

[26] For an overview of these studies, see Michael McGeary, "Appendix E: Recent Reports on Future Trends in Science and Technology," in *Future R&D Environments: A Report for the National Institute of Standards and Technology* (Washington, DC: National Academy Press, 2002), 100–128. The author summarizes the major findings contained in eight different reports published by US government agencies and non-governmental organizations within the last three years.

surprisingly, Japan, China, and other governments have followed suit and have identified increased government funding of basic R&D programs as a key task in their long-term development strategies.

A simple increase in funding, however, will not suffice to ensure sustained technological development or economic growth. Experience shows that, to be effective, government funding of R&D must be carefully managed and continuously monitored. Moreover, scientific research and technology transfers must be effectively coordinated among state-run laboratories, industry, and academia. At the same time, of course, there is a risk that government oversight and regulations can become too over-bearing, which could impede the innovative impulses they are intended to promote. Ultimately, the test of an effective strategy is whether government-funded R&D translates eventually into useful technological know-how (i.e., patents) or applications useful in either the civil or military sphere.

Another implication of globally dispersed R&D for national S&T policymaking is continued emphasis on tax credits and other financial incentives to attract both domestic and foreign high-tech investors. Even market economies such as the United States and many European nations maintain tax credit or rebate programs to foster sustained investment by industry in fundamental research.[27] Developing countries, too, are adopting this approach. In the PRC, tax-based incentives continue to be an important factor in attracting foreign direct investment: foreigners pay only a 17 percent tax on R&D-related investments compared to the 33 percent paid by domestic firms.[28] The increasingly widespread use of financial incentives is representative, in part, of the highly competitive nature of the global high-tech market.

The fierce competition for high-tech resources is growing in other areas as well. Many countries have implemented new policies to attract and, more importantly, to retain highly skilled technical workers who have become increasingly mobile both within the domestic economy and across international boundaries. The US economy already is heavily dependent on foreign workers to fill many high-tech positions and has remained so even in the midst of an IT market recession. At the same time, however, a growing number of these same talented individuals are

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[27] OECD, Science, *Technology and Industry Outlook 2002* (Paris: OECD, 2002).

[28] Tax rebates and other preferential policies geared toward foreign investors are supposed to be phased out under China's WTO commitments. However, policymakers in Beijing failed to announce a rise in tax rates on foreign investments during the 2003 National People's Congress, leading analysts to predict no change in policy until at least 2004. See "Tax Equalization Unlikely in 2003," *Far Eastern Economic Review* (March 20, 2003).

being enticed to return to their home countries to contribute to economic development there. Many are taking advantage of these policies, which advertise entrepreneurial opportunities and other benefits for returning expatriates. This enhanced competition for highly educated, technically skilled labor is reflected also in the growing number of government-sponsored fellowship and exchange programs, which are springing up around the world in a deliberate effort to attract foreign scientists and engineers whose contributions are valued, even if over only a short period of time.

The competitive pressures placed on attracting and retaining skilled laborers may ease somewhat over time given the increasingly networked nature of scientific research. More and more, even internationally dispersed researchers are able to collaborate, in some cases in real time. National policies designed to exploit all of these trends, however, must also take into account the effects of export control regulations and, in the United States, heightened homeland security concerns that could inadvertently deter international scientific exchanges.

Finally, to preserve over the longer term their ability to benefit from these global dynamics and guard against the possibility of an international "brain drain," many governments are placing greater emphasis on improving domestic education and instituting training programs in the physical sciences and engineering. This is a particular concern in the United States, where there is a shortage of students concentrating in math and science.[29]

Other recommended policy initiatives for dealing with a more science- and technology-oriented global market include improved processes for enforcing intellectual property rights, better national and international coordination in developing measures and standards, increased government promotion of domestic technology transfer mechanisms, and improved integration of scientific, technological, and industrial R&D assets. Aspects of all of these strategies are found across the globe as both developed and developing countries strive to gain from globalization's influence.

As indicated by the changing dynamics described above, globalization and the increasingly international character of high-tech R&D are having an impressive impact on economic development and

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[29] This is also recommended as part of US S&T policy. See President's Council of Advisors on Science and Technology (PCAST), *Assessing the US R&D Investment* (Washington, DC: 2002), available online at http://www.ostp.gov/PCAST/FINAL%20R&D%20REPORT%20WITH%20LETTERS.pdf.

S&T policymaking in the United States and beyond. But we do not yet know the full extent of these forces or their ultimate impact, as they are still ongoing phenomena. In particular, the growth in global R&D, although recognized as an important new trend, is not yet well documented nor well understood. Efforts are underway by the US government and international organizations to develop a system to more systematically collect data on these activities. In the meantime, however, much of the information available will remain anecdotal, piecemeal, and based mainly on observation. While these pieces provide a better picture, they are ultimately insufficient to fully gauge and effectively respond to the increasingly influential trend toward global R&D.

COOPERATION AND COMPETITION IN GLOBAL R&D

A particularly interesting aspect of the growth in global R&D is that it fosters both greater international cooperation and competition. As less developed economies become more engaged in advanced scientific and industrial R&D activities, the opportunities for cooperation will increase. At the same time, however, neo-mercantilist fears of zero-sum competition remain and are likely to grow with the appearance of newly competitive markets. Which strategy—cooperative or competitive—the United States and other countries favor will depend on many factors, but will be guided in large part by our understanding of the underlying dynamics and long-term costs and benefits of R&D globalization.

While data on international R&D activities remain sketchy, what is becoming clear in studies of the global economy is that a transformation is already under way toward development of so-called "knowledge-based economies." That is, by the end of the 20th century, economic growth and prosperity in many economies had come to depend less on gains from improved productivity of labor or manufacturing inputs than on commercially driven technological advances. In an economic environment emphasizing innovation (as experienced during much of the 1990s), individuals, enterprises, and governments share an incentive to spread—rather than to restrict or overly protect—knowledge. This is based not on altruism but on an expectation that innovative advances in one sector will—directly or indirectly—result in additional benefits by sparking technological advances in other areas as well.[30] Though it is

[30] This view is based not only on casual observation but on economic surveys conducted by the Council of Economic Advisors in the 1990s that found that R&D investments generally result in returns of as high as 20 percent for private investors and more than 50 percent return for society at large. In other words, every dollar invested in R&D contributes more than a dollar's worth of return to the economy overall. The concept of

impossible to predict exactly what new technologies might emerge when or where, the continuous cycle of innovation from the ever greater flow of knowledge fuels economic growth and, in effect, transforms knowledge into currency. Accordingly, governments everywhere hope to take part in this new-style economy and are implementing near- and long-term plans and policies to help them do so.[31]

As multinational corporations seek new markets and sources of innovation around the world, developing countries are fast becoming part of this new economic environment. The spread of high-tech R&D is one consequence of this dynamic. As long as globalization continues to be the driving economic force, we can expect to see further worldwide distribution of high-tech industrial and R&D capabilities. If, however, globalization appears to be slowing or other countervailing forces arise, the international R&D market would be similarly affected and these resources likely would be drawn back to fuel domestic economies.

At the moment, what the future holds is uncertain. Globalization may or may not continue to drive international relations. Although the attacks on 9-11 temporarily brought the United States closer to European and other allies, the subsequent global War on Terrorism has deeply divided allied relations, which remain strained in the aftermath of the debate over a war with Iraq. The possibility of future terrorist attacks on critical political or financial centers could lead international relations in new and less cooperative directions. There also is the risk of rising "techno-nationalism"—protective domestic policies intended to maintain or increase a nation's relative scientific and technological capabilities.[32] Whether as an inverse response to rising "techno-globalism" (i.e., technology-driven incentives favoring more open international trade) or

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innovation as a primary economic driver is not a new one, having been suggested by early theorists such as Adam Smith, Joseph Schumpeter, and even Karl Marx. These notions and the evolution of economic thinking on innovation are discussed in "Science, Technology, and Economic Growth," Chapter 2 in *National Forum on Science and Technology Goals, Harnessing Science and Technology for America's Economic Future: National and Regional Priorities* (Washington, DC: National Research Council, Office of Special Projects Policy Division, 1999).

[31] For an overview of how knowledge-based or "new economy" growth is affecting economic development overall, see Organization for Economic Cooperation and Development (OECD), *The Knowledge-Based Economy: A Set of Facts and Figures* (Paris: OECD, 1999).

[32] A number of studies have examined the push and pull of global technology opportunities, risks, and national interests. Among the more comprehensive are Sylvia Ostry and Richard R. Nelson, Te*chno-Nationalism and Techno-Globalism: Conflict and Cooperation* (Washington DC: The Brookings Institution, 1995); and Hamburg Institute for Economic Research, Kiel Institute for World Economics, and National Research Council, *Conflict and Cooperation in National Competition for High-Technology Industry* (Washington, DC: National Academy Press, 1996).

as part of a normal pendulum-like swing between national and global strategic, political, and economic pressures, techno-nationalistic tendencies are here to stay and could disrupt the present wave of globalization.[33]

Thus far, however, the prevailing international trends appear to have encouraged more global cooperation and healthy competition. This has, on balance, benefited the US economy and those of many nations, particularly in Europe and Asia. Consequently, both developed and developing countries continue to aspire to the realization of a knowledge-based economy. The high-tech market's downturn might have slowed this trend, but not reversed the spread of innovative impulses and investments. Recognizing this and the need for more detailed study and analysis of the global R&D phenomenon, the President's Council of Advisors on Science and Technology recently concluded that:

> More countries are becoming involved in R&D and more countries have a sizable research infrastructure. Awareness of other countries' activities and possible collaborations are becoming more important.[34]

With this in mind, this report examines the emergence in one developing country—the People's Republic of China—of foreign-invested, high-tech R&D and its implications for China's own development trajectory, for US competitive interests, and for future Sino-US relations.

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[33] Although the usual dichotomy pits techno-nationalism against techno-globalism, a third way—"neo-techno-nationalism—has been put forward to describe the simultaneous pursuit of nationalistic and global technology leverage. See Atsushi Yamada, "Neo-Techno-Nationalism: How and Why It Grows," paper presented before International Studies Association Convention, Los Angeles, California (March 14–18, 2000).

[34] PCAST, *Assessing the US R&D Investment* (2002), 7.

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Science, Technology, and High-Tech Development in China

"China's goal is to be among the top 10 most S&T-competitive nations by 2010."[1]

An essential factor in determining the significance of increasingly global R&D on China's development, US-China relations, and international trade more generally is the degree to which the PRC has the capacity to leverage these forces. Since Mao Zedong's civil war victory led to the formation of the People's Republic of China in 1949, PRC leaders have attempted through numerous phases and shifts in science and technology policymaking to modernize China's S&T development system. In 2003, yet another major reform of China's S&T apparatus and infrastructure is expected.[2]

A common characteristic in all of these reform efforts has been the PRC's attempt to catch up to the West. This objective poses a perpetual dilemma for Chinese officials over whether to try to leap ahead technologically or to follow a more incremental, absorptive strategy of S&T development in order to ultimately catch up to, if not surpass, the US and other industrialized economies over time. As this report goes to press, the debate in Beijing continues.

EVOLUTION OF THE CHINESE S&T SYSTEM

In 1978, at the historic Third Plenum of the Eleventh National Party Congress Central Committee meeting, China's paramount leader, Deng Xiaoping, announced the formal implementation of a series of "Four Modernizations" intended to guide the PRC into the modern era. These were, in order of priority:

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[1] Charles Larson, "New National Innovation System Seen as Key to Transforming China into a Market Economy," *Research•Technology•Management*, vol. 43, no. 2 (Washington, DC: Industrial Research Institute, 2000).

[2] "China Drafting Sci-Tech Development Program," *Xinhua News Agency*, in FBIS, FBIS-CHI-2003-0107 (January 7, 2003).

- Industry
- Agriculture
- Science and technology
- National defense / military

Having achieved the first two stages of modernization, Deng has left much of the remaining agenda to his successors. While this grand vision may no longer represent the formal roadmap for China's development, Deng's third modernization—science and technology—was and remains a high priority for the Chinese leadership.[3]

To understand the impact and long-term implications of globalization and foreign high-tech R&D investment on China's own technological and industrial development, it is important to consider the evolution of science and technology policy on the Mainland. Two major periods stand out: the pre-reform era and the years since China first began instituting market-oriented economic reforms. During both periods, progress toward reform was either delayed or accelerated due to overriding domestic political forces. From the PRC's formation under Mao in 1949 until Deng Xiaoping's ascension to power three decades later, China shaped its S&T programs according to the Soviet model. Once Deng's "Open Door" economic reforms began to take hold in the mid-1980s, China's S&T system also came under pressure to meet the demands of the marketplace. Over the last quarter century, progress toward modernization has proceeded steadily, if slowly.

Adopting the Soviet S&T Model (1949–1965)

From its earliest days, Chairman Mao declared that the PRC would "lean to one side"—that is, in world affairs China would side with the Soviet Union (rather than the United States). In 1950, the two

[3] While most closely associated with Deng, these four priorities were first announced as part of the Third Five-Year Plan (1966-70) and later formally put forward by Premier Zhou Enlai at the Fourth National People's Congress in 1975. However, Deng Xiaoping shifted S&T to a higher priority than military modernization, altering the original order in which military modernization was listed as the nation's third priority. See Library of Congress, *US Army Area Handbook: China* (Washington, DC: US Government Printing Office, 1987). The National Science Conference held that same year also reflected this heightened emphasis on S&T development, which is viewed as a key point in the evolution of China's S&T development. This observation is made in Richard Suttmeier and Cong Cao, "China Faces the New Industrial Revolution: Achievement and Uncertainty in the Search for Research and Innovation Strategies," *Report Memorandum*, no. 99-13 (Tokyo: National Science Foundation Tokyo Regional Office, November 26, 1999).

communist states formalized their relationship by signing the *Sino-Soviet Treaty of Friendship, Alliance, and Mutual Assistance*. Given their then-close bonds, it is not surprising that the PRC adopted essentially the same model of scientific, technological, and defense industrial development as its neighbor and ally. Yet, despite the alliance, security remained Beijing's overriding concern. In order to shield vital military, industrial, and technological capabilities from potential external threats, PRC leaders decided to position the nation's strategic technological assets—China's defense and heavy industry as well as the S&T research institutes that served them—in the nation's vast interior provinces. This inland location would comprise a "Third Front" thought to be beyond the reach of potential enemies.[4] This strategy, however, would have two long-term consequences. First, the PRC's S&T programs were, from the start, integrally linked with broader defense-oriented policies and practices.[5] Secondly, these S&T assets would be removed from the PRC's most dynamic economic growth areas along China's coastline, where the bulk of productive commercial enterprises are concentrated.[6]

China's leaders also adopted a centrally planned, highly bureaucratic, and strictly hierarchical structure similar to the Soviet S&T system. For instance, China's premier scientific institution—the Chinese Academy of Sciences (CAS)—was modeled closely on the Soviet Academy of Sciences. Consequently, however, China suffered from the same lack of cross-institutional communication, interaction, and effective coordination among its scientists and researchers (who were scattered and isolated across self-contained research institutions variously affiliated with CAS, government ministries, regional institutions, and Third Front defense research institutes) as the Soviet Union. While this type of vertically integrated system provided a degree of enhanced administrative control, ultimately it proved to be a serious obstacle to China's overall technological development and subsequent efforts to modernize the S&T system.

[4] This is also sometimes referred to as the "Third Line" according to the literal English translation of the Chinese term: *san xian*. For the definitive essay on this strategy, see Barry Naughton, "The Third Front: Defense Industrialization in the Chinese Interior," *The China Quarterly*, no. 115 (September 1988), 351–86.

[5] For a detailed exposition of the close relationship between military and civilian science and technology development efforts and reforms, see Evan A. Feigenbaum, "Who's Behind China's High-Technology 'Revolution'? How Bomb Makers Remade Beijing's Priorities, Policies, and Institutions," *International Security,* vol. 24, no. 1 (Summer 1999), 95–126.

[6] As of the mid-1990s, more than half of China's military/defense industrial research enterprises still were located in remote rural areas. John Frankenstein and Bates Gill, "Current and Future Challenges Facing Chinese Defense Industries," *The China Quarterly*, no. 146 (June 1996), 43.

In addition, PRC leaders shared the same socialist-inspired penchant for long-term, central planning of economic, industrial, and technological development as the Soviets. China's own formal five- and ten-year plans sketch out various long-term goals and "major tasks" deemed essential by PRC leaders. This practice continues today, despite China's many market-oriented reforms over the past two decades.

While China's early Cold War-era S&T system might appear hapless from today's perspective, at the time the system served Chinese leaders reasonably well. Within the first two decades of its founding, the PRC had demonstrated surprising technological achievements in the military sphere, including the successful development of nuclear weapons and ballistic missiles. Along with substantial technical assistance from the Soviets, the centrally planned nature of China's system helped leaders in Beijing to mobilize China's scientific—primarily Third Front—forces to achieve these singular objectives. However, it took an exceptional level of effort and enormous economic expense to achieve these milestones. Thus, while representing impressive technological advances, these feats proved atypical in China's overall S&T evolution.

Major Setbacks and a Lost Generation (1966–1976)

Despite these early achievements, China suffered significant national and international setbacks through much of the 1960s and 1970s, which inevitably affected overall S&T development. A fundamental shift in international orientation came with the Sino-Soviet split, which by 1960 had become apparent to the entire world and resulted in a suspension and then withdrawal of Soviet advisors, assistance, and technology. The split also seared into the Chinese memory the dangers inherent in becoming overly dependent on foreign aid and technology. Due to Cold War tensions and trade sanctions, Western aid in the form of technology assistance remained limited until President Nixon's historic visit in 1972 ushered in a new relationship vis-à-vis the United States. Even then, technological cooperation was viewed warily by both sides.[7]

[7] As Jim Mann recounts in describing Secretary of State Kissinger's initial attempts to forge a new strategic relationship by playing the "China card" against the Soviets: "At this early stage, the Americans were taking the initiative. This was not a case of China coaxing the United States to turn over military technology, as happened in later years." President Ford authorized the first major Western transfer of military technology to the PRC—British-engineered Spey jet engines—during a visit to China in 1975 (US approval was required under CoCom rules). A year later, he approved the sale of two US-built supercomputers. James Mann, *About Face: A History of America's Curious Relationship with China, From Nixon to Clinton* (New York: Alfred A. Knopf, 1999), 74–76.

China's technological progress also was stalled by periodic domestic political campaigns. Although intended to stimulate China's economy, comparative industrial strength and revolutionary spirit, Mao's "Great Leap Forward" (1958–60) proved disastrous. A truly radical experiment, the plan called for urban industrial laborers and collectivized agricultural communes in China's rural provinces to vastly increase production levels, an effort that resulted instead in economic collapse and widespread famine. Further political, social, and economic upheaval came several years later with the start of Mao's "Great Proletarian Cultural Revolution" (1966–1976). The enormous turmoil sparked by the radical fervor of Mao's "Red Guards" during this era effectively paralyzed Chinese society and stifled scientific development for more than a decade. During this period, the country's universities were shut down, and China's intellectual elite either fled or faced harassment, imprisonment, or worse. Consequently, the PRC continues to suffer the effects of an entire "lost generation" of smart, capable, and educated academics and professionals who were shut out during this unfortunate and chaotic period.

The "Open Door" and Growing Western Influence (1977–1997)

Following the political upheaval surrounding Mao's death in 1976 and the ensuing struggle for power in Beijing, Deng Xiaoping re-emerged from internal exile to lead the PRC in a new and more prosperous direction. The hallmarks of his now famous "Open Door" strategy instituted in 1979 were increased foreign trade, market-oriented economic reforms, institutional and legal reforms, and the importation of Western science, technology, and know-how intended to help catapult the PRC into the modern era. This formative period would witness several milestones, marked by periodic reviews of lessons learned as well as new ideas and strategies for accelerating China's modernization.

Growing International S&T Cooperation

As part of his Open Door initiative, Deng Xiaoping visited the United States in January 1979. He came away with a bilateral agreement on S&T cooperation that remains in effect today.[8] Government-

[8] For an extensive overview of the impact of this far-reaching agreement, see US Department of State, *US-China Science and Technology Cooperation* (Washington, DC: US Government Printing Office, 2002). The US Congress requested the review be conducted by the US State Department in cooperation with the US-China Security Review Commission's work as cited in Conference Report 107-360 accompanying the US Department of Defense Appropriations Bill for FY2002 (H.R. 3338). The US-China S&T Agreement has been renewed every

sponsored research collaboration under this agreement and its many subsequent protocols, annexes, and other related accords continues apace, involving no less than eleven different US federal agencies. While the contribution this agreement has made to China's overall industrial, economic, or military success is difficult to gauge (the State Department characterizes it as modest at best), there is no doubt that the continuous scientific and technical exchanges that this agreement makes possible have had a profound effect on the PRC's approach to S&T development. Many of the reforms Beijing has implemented over the last quarter century reflect strategies, priorities, and lessons learned from the West, particularly the United States.

The US-China S&T Agreement was only one of a series of collaborative S&T-related arrangements the PRC implemented with other industrialized nations around this time. A key objective in all of these accords was the exchange of scientific and technical personnel as a means of acquiring advanced technological training and know-how. The Chinese interest in personal exchanges as a vehicle for technology transfer came as a result of lessons learned from earlier decades when the PRC favored wholesale transfers of entire plants, turnkey facilities, and heavy industrial equipment (primarily from the Soviets) instead of the fundamental know-how underlying these capabilities and technologies. This practice did not yield the necessary understanding China needed to build on (or successfully reverse engineer) advanced technologies, which became apparent once Soviet aid ended. Thus, China's opening to scientific and technological exchanges of personnel reflected a conscious decision to "acquire the hen and not just the egg" in future technology transfers.[9]

As a result of the PRC's new openness, hundreds of thousands of Chinese have since had the opportunity to study abroad. The vast majority have attended American universities. While running the risk of a serious "brain drain" from the Mainland, this policy, perhaps more than any other Chinese S&T development measure, has provided China with long-term tangible and intangible benefits.[10] It also has allowed China to

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five years since its inception; the last renewal was agreed to in April 2001. The State Department has estimated the annual cost of this collaboration to be approximately five million dollars (funding for Chinese participation is provided by Beijing).

[9] See "The Chinese Context for Technology Transfer: Strategies and Issues for Technology Imports," Chapter 3 in US Congress, Office of Technology Assessment, *Technology Transfer to China,* OTA-ISC-340 (Washington, DC: US Government Printing Office, July 1987), 41.

[10] The number of Chinese students studying abroad each year far outpaces those who return; less than half of those trained abroad over the past two decades have returned to the PRC. The number of returnees is growing,

regain much of the ground lost during the Cultural Revolution, helping to train a new generation of scientists, engineers, and researchers to take the place of China's aging scientific community. At the same time, the ever-increasing numbers of China's best and brightest studying and working abroad have infused the international scientific community with new, young talent while enhancing global R&D collaboration.

The First of China's Special Trade and Investment Zones Appears

Another significant and early reform dating back to this period was the introduction of Special Economic Zones (SEZs) in 1979. While primarily an economic reform measure, the SEZs were only the first of several other types of experimental new development and direct-investment zones that have come to play an important role in China's technological modernization.

The SEZs were established purposely far from the capital along China's southeastern coastal areas: in Fujian Province (opposite Taiwan) and Guangdong Province (outside Hong Kong). These zones represented the PRC's first cautious attempts to implement market-oriented economic reforms and to open wide the door to foreign investment and technology. While these zones were successful overall in attracting foreign investment, the SEZs initially did not lure the desired high-tech industries as intended. Rather, light industry and low-tech commercial manufacturing have dominated investment in these areas.

To encourage additional, more advanced forms of foreign investment, Chinese leaders expanded on this model by announcing the formation of several new types of investment zones. From 1984 to 1995, the PRC established special Economic and Technological Development Zones (ETDZs), Free Trade Zones (FTZs), and High Technology Development Zones (HTDZs).[11] In these cordoned areas, foreign-invested enterprises, Sino-foreign joint ventures (JVs), and now wholly foreign-owned enterprises (WFOEs) are allowed and openly encouraged

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however, thanks to continued economic growth on the Mainland (contrasted with the continued IT industry downturn and shrinking number of high-tech positions available in the United States). Also attracting returnees to the PRC are growing entrepreneurial opportunities and increasingly generous Chinese government incentives for technically skilled expatriates. Terrence Chea, "Looking Homeward: Business, Social Opportunities Await US-Educated Chinese," *Washington Post* (January 28, 2002), E01.

[11] ETDZs also are referred to as Economic and Trade Development Zones. For a more detailed listing and description of the evolution of these various investment zones, see Kathleen Walsh, "Part I: Technology Transfer: Policies, Processes, and Decisionmaking in China," in *US Technology Transfers to China* (Washington, DC: US Department of Commerce, Bureau of Export Administration, 1999).

to transfer foreign technology and know-how along with building manufacturing, export-processing, and assembly plants. Foreign investment in these corridors is attracted by special regulatory treatment, preferential customs and tax rates, and other financial incentives designed to lure the world's leading high-tech commercial enterprises. As such, China's special economic and other investment zones have become the main engine for growth in the Chinese economy.

These zones are also the primary conduits for foreign commercial technology transfers. As noted earlier, however, with the exception of the expansive HTDZs, most of these investment zones are located in coastal areas far from China's defense industrial enterprises, which monopolized most of the nation's S&T assets through the mid-1980s. In order to exploit the growing influx of foreign investment and technology, leaders in Beijing decided a new strategy was needed to accelerate scientific and technological development.

Revising China's S&T Development Strategy: Linking S&T to the Economy

By the mid-1980s, two things had become clear: first, the concentration of China's S&T assets in the interior and Third Front defense industrial sector had become a serious impediment to further technological modernization in either the military or civilian sectors, and, second, the nation's scientific and research work must be tied more closely to industrial development and production. To address these concerns, over the next decade Chinese leaders instituted several major reforms that continue to influence China's scientific and economic development today.

The year 1985 was a watershed for Chinese S&T policymaking. In March of that year, the Central Committee of China's Communist Party announced its "Decision on Reform of the S&T Management System."[12] A landmark policy reform, it definitively stated the following:

> Modern science and technology constitute the most dynamic and decisive factors in the new productive forces. . . . We should reform China's science and technology management system resolutely and step by step in accordance with the strategic principle that our economic construction rely on science and technology and that our

[12] International Development Research Centre (hereafter IDRC), "Innovation and a National System of Innovation," Chapter 5 in *A Decade of Reform: Science and Technology Policy in China* (Ottawa, Canada: IDRC, December 1997).

> scientific and technological work must be oriented to economic construction. . . .

This Decision was a turning point in China's developmental strategy, which henceforth was focused primarily on market-oriented and technology-based industrial development. Among the reforms set forth in this Decision was a change in central government management of S&T activities, with a shift toward instituting a more limited and effective oversight role while allowing greater decision making at the local and institutional level. Henceforth, the central government role primarily would be to provide "guidance," rather than automatically allocating financial support for R&D. This meant, for the first time, civilian and military researchers would have to compete for government R&D funding. The Decision also called for greater collaboration and coordination among China's research institutes, universities, and industrial commercial and defense enterprises in order to accelerate the commercialization and practical application of S&T research results. In addition, these reforms sought to improve China's absorption of foreign technological know-how by opening channels to foreign S&T experts and technologies as well as "rationally" redeploying domestic S&T personnel (i.e., relocating researchers nearer to commercial enterprises and production lines). This strategy for reform and enhanced technology development set China on a course toward becoming a more modern, high-tech economy.

Following the landmark decision in 1985 came a series of ambitious and long-term national S&T development plans.[13] These national programs were intended to guide China's scientific and research efforts away from the centrally planned, hierarchical, state-funded system and toward accelerated development of science and technology more responsive to China's industrial, commercial, and defense needs. While still overseen and funded by the central government, local PRC officials have adopted different strategies for implementing these policies based

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[13] China's first long-term, national high-tech development strategy was announced prior to the Decision, in 1982. The "National Key Technologies Research and Development Program" continues to guide R&D development in five key areas: biotechnology, manufacturing automation, information technologies, new energy technologies, and advanced materials.

on regional as well as local interests, industries, and infrastructures.[14] These plans, still under way today, include the following:[15]

- *Spark Program* (1986): This initiative focuses on development of China's rural economy by applying scientific and technological advances to agriculture, often via pilot programs and through "Spark Technology Intensive Zones." The program also promotes popularization of S&T in rural areas as well as technical training for China's vast rural population.

- *Program for Hi-Tech Research and Development / Program 863* (1986): This program highlights China's strategic R&D priorities, concentrating on basic and advanced applied research in eight key areas: automation technology, biotechnology, energy technologies, information technology, laser technology, new and advanced materials, marine technology, and space technology. China's strategic weapons scientists initially proposed the need for this program, which has the distinction of having been personally approved by Deng Xiaoping in March 1986 (as reflected in the program's name). However, the program's continued emphasis on strategic civil and military technology development and its stated objective of achieving technological parity with the industrialized nations has made it, at times, a controversial prospect for foreign investment.[16]

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[14] For a highly detailed, interesting new study on the different municipal approaches taken in pursuing S&T development see Adam Segal, *Digital Dragon: High-Tech Enterprises in China* (New York: Council on Foreign Relations, 2003).

[15] These brief program descriptions are based in part on detailed information provided—in English and Chinese—on the website of the Ministry of Science and Technology (MOST), which oversees many of these programs. The year each program started is indicated in parentheses.

[16] Due to this program's broad-ranging goals, Chinese officials apparently have had a hard time evaluating its success, and the program's large funding levels may have been inefficiently and ineffectively allocated, according to a senior Chinese scientist (Interview, Beijing, July 2002). The 863 Program is also sometimes referred to as the "Advanced Research Program." See William R. Boulton, Michael J. Kelly, and Phyllis Genther Yoshida, *Information Technology in the Development Strategies of Asia* (Washington, DC: International Technology Research Institute, September 1999). At least five of the key sectors are overseen by the Ministry of Science and Technology; only one—marine technology—is managed under the State Oceanic Administration. The Commission on Science, Technology, and Industry for National Defense (COSTIND) reportedly oversees the space and laser programs. See Embassy of the People's Republic of China, "Overview of China's S&T System Management System." COSTIND's role is cited in Richard Suttmeier and Cong Cao, "China Faces the New Industrial Revolution: Achievements and Uncertainty in the Search for Research and Innovation Strategies," *Report Memorandum* no. 99-13 for the National Science Foundation, Tokyo Regional Office (November 26, 1999), 4. For the most detailed account of the 863 program's origins and the role of China's strategic weaponeers

- *Torch Program* (1988): Torch projects emphasize high-tech industrial development and applied research, particularly the commercial application of research advances achieved through the 863 program. Under the Torch Program, China has established 53 state-level High Technology Development Zones (HTDZs), many more local and regionally based high- and new-technology development zones, as well as hundreds of technology and business incubation centers often located within these zones. Among the zones established under the Torch program is Beijing's impressive Zhongguancun corridor located in the northwestern Haidian District, the home of many multinational firms and China's own high-tech entrepreneurs, research institutes, and leading universities. The Torch Program seeks to create in these zones an environment and infrastructure conducive to high-tech innovation and actively seeks international partners to collaborate and invest in high-tech industries. Within these zones, enterprises designated under the Torch Program as new- or high-technology firms (including R&D centers) enjoy preferential treatment in terms of state funding, construction loans, as well as tax rates and rebates.

Comment: Find ref for IRI 2002 piece by Albrecht that states "Originally 53 in number, the government recently decided to focus on five parks in major urban centers to better promote transfer of new **technology** and productive practices to the marketplace and to PRC manufacturing enterprises"

- *National New Products Program* (1988):[17] This program supports R&D efforts that result in new high-tech products, particularly those based on new intellectual property, produced primarily (80 percent or more) with components produced domestically, have high export potential, or are compatible with international standards.

- *National Science and Technology Diffusion Program* (1990):[18] This program provides support to state-owned enterprises for applying scientific and technological R&D results to commercial applications. Successful R&D programs are granted recognition and included in an annual "Guideline of Programs" list for possible investment by commercial enterprises. The program is funded through state loans, local government funding, and enterprise-invested capital.

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in overhauling the PRC's S&T system, see Evan Feigenbaum, "Who's Behind China's High-Technology 'Revolution'? How Bomb Makers Remade Beijing's, Priorities, Policies, and Institutions."

[17] Another name for this program is the "Trial Production and Appraisal Program."

[18] This program also is known as the "Major Achievements Promotion Program" or the "National S&T Achievements Spreading Program."

- *National Basic Research Priorities Program* (1991):[19] This program promotes continued emphasis on basic scientific research.

- *National Basic Research Priorities Development Program / 973 Program* (1997):[20] This program takes a forward-looking, multi-disciplinary, strategic approach to identifying and promoting China's basic R&D, science, and education needs in areas such as economic and high-tech development, environmental and ecologically friendly technologies, and improved energy and health care resources.

As these reform-era S&T development programs reflect, China's scientific community has been pushed to "jump into the sea"—to redirect their efforts toward more market-based, results-oriented research. These national S&T development programs are intended to help guide this transition by providing incentives for innovation and entrepreneurship as well as by limiting allocations of state funds to the most productive institutes and enterprises, thereby forcing researchers and institutions to compete for state resources. To date, the Torch and 863 Programs have had the most far-reaching impact and success, particularly in the computer and telecommunications industries.

Revitalizing China's S&T Modernization Efforts in the 21st Century

A decade after the 1985 "Decision on the Reform of the S&T Management System" was announced, Chinese leaders reiterated these S&T goals in a joint Chinese Communist Party Central Committee and State Council "Decision on Accelerating Scientific and Technological Progress," issued in May 1995 just prior to the National Conference on Science and Technology. This new document ushered in a second phase of major reforms that would build on existing S&T programs while "revitalizing the country through science and education."[21] In part, the 1995 Decision was an effort by China's next generation of leaders to put their stamp on China's S&T policymaking and modernization efforts. It also came at a time when foreign investment had exploded—following

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[19] This is also known as the "Scaling Heights" or "Climbing" program.

[20] It appears that this program, the one above, and a 1985 "Major Programs of the National Natural Science Fund" have together been subsumed under a new "National Basic Research Priorities Program." See Embassy of the People's Republic of China, "Overview of China's S&T Management System," available online at http://www.chinaembassy.org.nz/eng/35206.html.

[21] Quoted in Suttmeier and Cao, 3.

the post-Tiananmen slump, foreign investment surged, making 1993 the peak year for foreign direct investment in China. Chinese leaders sought to better exploit this trend in order to move China's technological modernization efforts forward, particularly given the high-tech military demonstration by US forces they had witnessed during the 1991 Gulf War.[22]

In addition, looking out to 2010, the 1995 Decision outlines a series of goals, including placing greater emphasis on education and training; establishing joint ventures (with domestic or foreign partners) and promoting domestic venture capital; collaborating with foreign experts and joint venture partners to acquire technology and know-how; increasing government spending on S&T (up to 1.5 percent of GDP by the year 2000 as cited in the Ninth Five-Year Plan); promoting sustainable development programs and technologies; increasing domestic innovations in key industry sectors; and developing advanced technological capabilities to "match those of the advanced countries in some fields."[23]

The Decision also emphasizes international cooperation and collaboration, stating:

> International S&T cooperation is an important aspect of China's policy of openness to the outside world. China is ready to enter into cooperation with any country depending upon the needs of Chinese S&T and economic development, according to the principles equality and mutual benefit, mutual enjoyment of benefits, protection of intellectual property rights, and respect for standard international practice. Cooperation can be bilateral, multilateral, with private parties or with governments in foreign countries at any level or through any channel. The government should give export credits and tax rebates to exporters of high tech products. S&T workers, especially young and middle-aged ones, should participate in international scientific meetings.[24]

What is most remarkable about the 1995 document is the public release of an accompanying study assessing China's progress and lessons learned during the first ten years of reform. This lengthy, over 400-page

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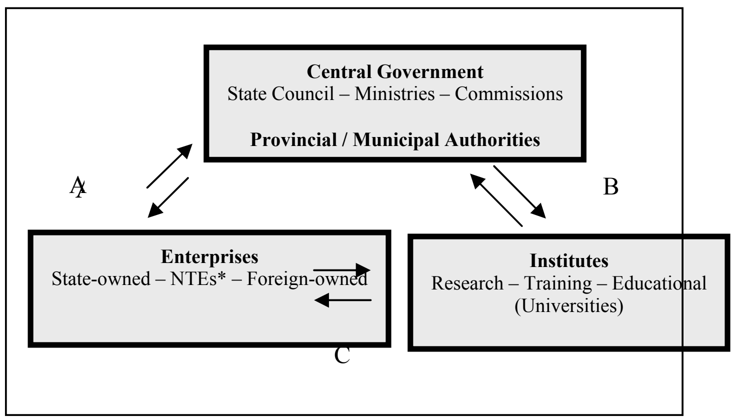
[22] Ibid. 2–6.

[23] For the text of this Decision as well as a useful commentary on this and related documents, see US Embassy, Beijing, "PRC State Council on 'Decision on Accelerating S&T Development'" (November 1996).

[24] "Decision on Accelerating S&T Development," Sections 35–36: "Increase Openness, Increase International Cooperation."

report provides a very candid and critical look at the remaining challenges and future problem areas in China's continuing quest to advance its scientific and technological capabilities. The influence of Western ideas on science and technology innovation in the PRC is clearly evident in the review, which includes an evaluation of S&T policymaking in a number of other countries, namely Germany, Japan, South Korea, the Soviet Union, and the United States. The study also outlines concerns for S&T development related to China's entry into the World Trade Organization.[25] While the PRC continues to face numerous challenges in modernizing its S&T system, the leadership's willingness to openly face, discuss, and learn from past difficulties bodes well for China's future progress.

Figure 6: An Evolving PRC National Innovation System



* NTE = New Technology Enterprise
Source: Adapted from Wu Guisheng, Xie Wei, and Li Jizhen, "The Evolving Technology Acquisition System in China from the Perspective of a National System of Innovation," *Report for the National Science Foundation's Tokyo Regional Office*, no. EAPRM01-04 (January 16, 2001).

Finally, the early 1990s also witnessed a fundamental shift in Chinese S&T policymaking from merely implementing R&D policies to establishing a more modern approach to S&T development by pursuing a National System of Innovation (NSI). To achieve the latter requires more than top-down, central government mandates or even incentive programs to guide research institutes and enterprises; it requires a

[25] State Science and Technology Commission (since renamed the Ministry of Science and Technology), "Science and Education for a Prosperous China" (Beijing: Central Party School, 1995), excerpts and commentary provided by the Environment, Science and Technology Section, US Embassy, Beijing, available online.

comprehensive, coordinated, and inclusive approach to science and technology development:

> An NSI can be thought of as a set of functioning institutions, organizations, and policies that interact constructively in the pursuit of a common set of social and economic goals and objectives and that use the introduction of innovations as the key promoter of change.[26]

In other words, an NSI entails an overarching strategy to exploit the contributions to S&T development made by various stakeholders: government bureaus, local administrators, universities, research institutes, and, most importantly, the marketplace. Over the course of the post-1985 reform era, PRC leaders have adopted this more complex approach to S&T policymaking, recognizing that additional institutional reforms and more dynamic and productive interactions between scientists, researchers, and enterprises are essential to China's modernization. In the PRC model, all stakeholders have a role in advancing and acquiring technology, but it is the emerging links between enterprises and institutions (link "C" in Figure 6 above) that have been the primary focus during the post-1985 reform era.[27]

Institutional Reforms Contribute to Enhanced S&T Development

Accompanying the policy changes outlined above have been a number of important institutional reforms that continue to impact China's efforts to develop indigenously more advanced technologies. In 1986, the PRC established the National Natural Science Foundation (NSFC). Modeled after the US National Science Foundation, the purpose of the NSFC is similarly to promote basic research in new and critical areas, to coordinate S&T research programs, and to enhance the professionalization of China's scientific community.[28] The NSFC introduced the use of peer reviews and evaluated for the first time

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[26] This concept was discussed with Chinese policymakers through a historic exchange with outside analysts from the IDRC who were invited by the PRC to assess China's S&T system and reforms instituted since 1985. See IDRC, "Innovation and a National System of Innovation," Chapter 5 in *A Decade of Reform: Science and Technology Policy in China* (Ottawa, Canada: IDRC, December 1997).

[27] Wu Guisheng, Xie Wei, and Li Jizhen, "The Evolving Technology Acquisition System in China from the Perspective of a National System of Innovation," *Report for the National Science Foundation's Tokyo Regional Office*, EAP Report Memorandum no. 01-04 (January 16, 2001).

[28] The NSFC differs from its American counterpart in two ways: it is devoted only to the natural sciences and its members are permanent employees. Deh-I Hsiung, "An Evaluation of China's Science & Technology System and Its Impact on the Research Community: A Special Report for the Environment, Science & Technology Section, US Embassy, Beijing" (Summer 2002), 29.

research proposals and achievements on the basis of scholarship and merit.[29]

Another important institutional reform was the creation in 1992 of National Engineering Research Centers (NERCs). These centers promote applied research and engineering in priority industry sectors such as China's designated "pillar industries" and other high- and new-technology sectors. Included among these are electronics, telecommunications, manufacturing and machinery, light industry and textiles, metallurgy, medicine, advanced materials, and other key industries. The main purpose behind these centers is to link (or "spin-off") research conducted by primarily CAS-affiliated research institutes to manufacturing processes and production. In addition, according to a NERC brochure, the centers' engineers are expected to "actively import, digest and absorb foreign technologies so as to support enterprises in their technological progress and structural readjustment." For this purpose, NERCs are able to import (duty-free) equipment and technology.[30]

The NERCs' overall program objective is to transform R&D more rapidly into new and innovative products, applying new management techniques and teamwork to achieve this objective. The Ministry of Science and Technology (MOST) oversees the NERC program and periodically evaluates the progress of each center, some of which have received World Bank funding. The centers are funded for the first three years, after which time each must achieve the milestones set out in a state-approved development plan. Those centers that do not perform accordingly are given a grace period during which to meet their goals. But, unlike in pre-reform days, NERCs that fail to meet their stated goals within this timeframe, or after two consecutive reviews, will have their NERC designation (and funding) withdrawn.

Of course, this is how the NERC funding and evaluation programs are supposed to work, which is not always reflected in the real world. Scientists from more than one NERC have complained of an overly complicated application process and harbor other concerns about excessive bureaucratic red tape. For example, the central government apparently does not always disperse monies approved for NERCs in a

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[29] Wendy Frieman, "The Understated Revolution in Chinese Science & Technology: Implications for the PLA in the 21st Century," in *China's Military Faces the Future*, James Lilley and David Shambaugh, eds. (Armonk, NY: M.E. Sharpe, September 1999).

[30] Author interviews with NERC staff (March 1998).

timely manner, leaving the centers to rely on other funds to pay for lab construction and other operating expenses. Nor does the importation of foreign equipment always go smoothly, due sometimes to customs and export control issues.[31] Obviously, such concerns could make it difficult for any institute or enterprise to operate efficiently. As a result of these and other challenges, the level of success among the NERCs varies, and it is not clear that funding is, in fact, withdrawn from non-performing centers as indicated by the program's parameters.

Over time, the NERCs are expected to become self-financing enterprises through commercialization of new products and fees from technology consulting services. Those centers receiving loans guaranteed by the government are expected to repay them over a period of time. It is hoped, too, that these centers will become financially self-sustaining by exporting their products. In addition, the centers are encouraged to develop new, indigenous, high-tech industry standards.[32]

In addition to establishing the NERCs, Beijing has designated more than 150 "State Key Labs" that are intended to raise the standard of research and training in China's university and state-run research institutes. These labs are administered according to professional scientific and merit-based rules and procedures.[33]

Also during the reform period, the Chinese Academy of Sciences experienced significant institutional changes. CAS scientists and researchers have faced the same state-imposed funding hardships and incentive programs as other state-run institutes. In response to these pressures, numerous CAS departments and researchers have opted to establish "spin-off" enterprises, some of which have become leading Chinese high-technology companies. Among the list of CAS spin-offs is Legend, China's leading personal computer manufacturer.[34] Since the reforms, non-governmental high-tech enterprises (*minying keji qiye*) such as this have proliferated throughout China, becoming—like Legend—an influential segment in China's technological development.[35]

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[31] Interview with NERC scientist (March 1998).

[32] Ministry of Science and Technology website (http://www.most.gov.cn/English/Programs/Engineer_c/menu.htm); Walsh, 10–11.

[33] Suttmeier and Cao, 3 and 7.

[34] CAS directly oversees six commercial enterprises and indirectly has interests in nine others. See CAS, "High-Tech Industry Development," CAS website (undated).

[35] Segal, *Digital Dragon: High-Technology Enterprises in China*; Qiwen Lu, *China's Leap into the Information Age: Innovation and Organization in the Computer Industry* (New York: Oxford University Press, 2000), 11–12.

More recently, the Academy has focused on a new and wide-ranging "Knowledge Innovation Program" (KIP). This effort is similar to initiatives in other countries to establish national innovation systems and "knowledge-based economies" (as discussed in Chapter Two). In China, the KIP program has Jiang Zemin's personal endorsement, and the State Council's Leading Group for Science & Education ratified the program's pilot phase in 1998. Following the program's initial period (1998–2000), the current objective is a full implementation of the program by 2005. The KIP program's overall goal is to achieve a knowledge-based economy by 2010.[36]

Each phase of the KIP program is ambitious and mirrors China's long-term S&T development plans, emphasizing the expansion of S&T know-how and access throughout Chinese society, including China's Western provinces. Fundamental, strategic research and innovation are prominent objectives, as is expanding CAS' scientific and technology exchanges with the international community. The KIP plan also highlights the development of new technologies and patents. Finally, the program focuses on professionalizing China's scientific community and connecting scientists, engineers, and technicians through formal and informal as well as electronic networks.

In addition to instituting the major KIP initiatives, the Chinese Academy of Sciences has undergone a large restructuring, designed to reduce its overall number of research institutes. Some are being transformed into enterprises, and others are being redirected to better meet the needs of the state.[37] Another high priority is recruiting recent graduate students and professionals in the engineering and basic sciences, whether in China or studying abroad. These efforts—known as the "Hundred Talents Program," "Overseas Chinese Talents Program," and the "Distinguished Overseas Scholars Program"—are critical to China's long-term prospects for becoming a high-tech and innovative economy.[38]

The Chinese Academy's KIP program and restructuring efforts are clearly meant to both jump-start and broaden scientific activity throughout China's technical community. The goal is to more effectively leverage existing S&T capabilities in order to exploit the

[36] See CAS, "Main Goals for the Phase of All-round Implementation of the KIP Pilot Project," and "An Outline of the CAS Action Plan for the Development of Western China," CAS website (undated).

[37] CAS, "Progress in the Initial Phase of the KIP Pilot Project," CAS website (undated).

[38] Ibid. See also, CAS, "CAS in 2002: Recruitment of High-Caliber Experts" (April 3, 2003).

advantages of globalization. But CAS' recruiting programs also reflect the difficulties China appears to be having in retaining researchers in its state-run institutes due to the rapidly expanding—and financially more rewarding—semi-private sector that has emerged in the PRC. Other difficulties persist as well, leading the Academy to announce in 2001 yet another new initiative as part of the KIP program: the "Strategic Action Plan for S&T Innovation" (SAPI). In announcing the new program, the Academy stated:

> It is a necessary approach to further promote the mechanism restructuring, institutional reform, development of the research contingent and an innovation-oriented culture at the Academy. It is the only way for the Academy to build itself into a scientific research base up to international standards, a base for producing high-level S&T experts and a base that serves to promote the development of high-tech industries in China. It is also a necessary step for the upgrading of the national capacity for S&T innovation.[39]

As this statement makes clear, Chinese leaders recognize that much more work remains to be done to effectively transform the PRC's sizeable scientific capabilities into more productive and market-oriented enterprises, particularly those located in the far Western provinces.

Finally, one other area of institutional reform stands out: China's universities have undergone an impressive institutional revitalization during the reform era. Recovering from the purges of the Cultural Revolution, university-based research institutes have enjoyed growing prominence in R&D funding and research contracts, particularly via grants awarded by China's NSFC.[40] As with state-run institutes, China's academic researchers were driven by state policies to become more self-sufficient in R&D funding. This led many to contract out their services to other research institutes, enterprises, and foreign investors. By the mid-1990s, universities increasingly also were playing host to R&D programs, centers, or labs sponsored by high-tech MNCs. These programs are concentrated at China's premier universities in Beijing and Shanghai, but can be found also at universities elsewhere, particularly those associated with science parks and high-tech development zones.

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[39] CAS, "Strategic Action Plan for Science and Technology Innovation," CAS website (undated).

[40] Suttmeier and Cao, 3.

Legal Reforms Promote S&T and Commercial Technology

Another characteristic marking the post-1985 reform period has been legal reform. These reforms have helped promote foreign high-tech investment and provided the necessary legal protections for indigenous innovation. Over the last two decades, the PRC has promulgated (and, in most cases, updated) new laws governing the production, transfer, and protection of scientific research, technology, and intellectual property.[41] The major technology-related legal reforms include the following:

- *Trademark Law* (adopted 1982, amended 1993, updated 2001 and 2002): This law outlines trademark authority, procedures, the use of trademarks, and an adjudication process. However, the law does not provide equal treatment to foreign trademarks and requires the use of Chinese legal services to register a foreign trademark.[42]

- *Technology Contract Law* (1987): This law standardized technology agreements covering the commercialization of research results and termination thereof. The law applies only to contracts between domestic persons and enterprises.

- *Patent Law* (first adopted 1984, amended 1993, updated 2000 and 2001): This law sets out for the first time China's patenting procedures, dispute resolution guidelines, and the legal rights of inventors, which now extend out to 20 years. Under this law, however, patent applications can only be filed by a registered Chinese patent service, which foreign investors must hire for this purpose.[43]

- *Copyright Law* (adopted 1990, updated 2001): Covering both domestic and foreign copyright applications, this law includes computer software under the definition of protected "works." It also

[41] Official English-language texts of these laws also are available on the MOST website. Years cited in association with Chinese laws vary depending on whether indicating the date a law was first announced or actually entered into law; the years cited here reflect the former.

[42] China established in 1998 a new State Intellectual Property Office (SIPO) to administer patent, trademark, and copyright policies and enforcement activities. See David Snodgrass, *China Country Commercial Guide FY2003,* no. 106626 (Beijing: US Embassy, 2002), 18.

[43] Snodgrass, *China Country Commercial Guide FY2003,* 17.

sets out contract rules, ownership rights, copyright procedures, and liabilities.[44]

- *Product Quality Law* (1993): This law governs both production and sale of products in the PRC, outlining liability and quality control specifications.

- *Law on Promoting the Transformation of Science and Technology Achievements* (1996): According to its text, this law covers the "activities of conducting follow-up experiments, development, application and popularization of scientific and technological achievements of practical value, which have been made through scientific research and technological development, thereby developing new products, new techniques and new materials and forming new industries in order to raise the level of productive forces." For the first time, this law provided specific guidelines governing domestic and foreign technology transfers (including R&D), enhanced intellectual property rights and protections for technology collaboration (including trade secrets, payment of royalties, and liabilities due to violations), and promoted the use of venture capital in developing high-risk, new-technology enterprises.[45]

As indicated above, a number of Chinese laws have been updated within just the past few years in response to China's pending WTO membership. Revisions have been made to laws governing foreign equity joint ventures, wholly foreign-owned enterprises, venture capital investment, tax collection, and other laws to bring them more closely in line with international standards. Also in relation to China's WTO commitments, the PRC in recent years has promulgated new regulations

[44] Other legal reforms, such as the "Computer Software Copyright Registration Measures" issued in February 2002 (updating the original 1991 regulations), eliminate the need for companies to register software with state authorities in order to enjoy copyright protections.

[45] Dalton, Kelly, and Yoshida, "Information Technology in the Development Strategies of Asia," 46.

governing computer software development and integrated circuit designs.[46]

Among the more important reforms vis-à-vis technology development was the April 2001 "Decision on Amendments to the Implementation Rules of the Law on Wholly Foreign-Owned Enterprises" (WFOEs). Issued by the State Council, the Decision eliminates conditions for approval of, and subsequent requirements on, WFOEs related to technology transfers, local content requirements, export quotas, and other non-competitive provisions.[47] Indeed, the PRC has committed across the board not to condition foreign investment or import licenses on the transfer of technology-related offsets (side agreements), although this is still "encouraged."[48]

As a result of these and other investment and technology-related legal reforms, China's S&T system and economy are comparatively more transparent, more market-oriented, and less subject to control or interference by state authorities. Nevertheless, still more improvements are needed.[49] But if carried through, these reforms and those sure to follow should encourage more dynamic interactions among innovative domestic and foreign entities in China.

Information Infrastructure is Needed to Fuel S&T and Economic Development

By the mid-1990s, it had become clear that another serious obstacle to China's technological development lay in the nation's relative lack of advanced communications infrastructure. At the time, only three out of every 100 residents had access to a non-public telephone, and one out of 400 had computer access.[50] Although foreign investors were anxious to

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[46] In January 2002, the PRC enacted for the first time "Regulations on Computer Software"; the "Regulations for the Protection of the Design of Integrated Circuits" were enacted in October 2001. Thomas T. Moga, "The TRIPS Agreement and China," *The China Business Review*, vol. 29, no. 6 (November-December 2002).

[47] Michael E. Burke IV, et al. "Foreign Law Year in Review: 2001—China Law," *The International Lawyer*, vol. 36 (Washington, DC: American Bar Association, 2001).

[48] See United States Trade Representative, *2002 Report to Congress on China's WTO Compliance* (Washington, DC: US Government Printing Office, December 2002).

[49] China remains under "Section 306" monitoring by the US Trade Representative's office due to continuing concerns over enforcement of IPR, copyright, and trademark rights. US Trade Representative, *Special 301 Report 2002* (Washington, DC: US Government Printing Office, April 2002).

[50] Cited in Peter Lovelock, et al., "China's Golden Projects: Reengineering the National Economy," *Harvard Business School Case Study* no. 9-396-283 (revised December 30, 1996), 3.

address this need, leaders in Beijing feared becoming over-dependent on foreign investment and technology, which would lead to the neglect or relative backwardness of indigenous capabilities in these critical technologies. Beijing also intended to leverage communications technologies to achieve more effective and efficient nation-wide administration, an ambition Chinese leaders have long dreamt of but have yet to achieve. To meet these objectives, officials announced in 1994 the creation of two additional Chinese telecom companies to compete with the Ministry of Posts and Telecom, and the start of what collectively would be called the "Golden Projects."

Initially there were only the "Three Goldens," a concept for three electronic infrastructure projects put forward by the Ministry of Electronics Industry. Since then, other government ministries have added their own programs to the list. As a result, there are presently no less than 20 separate information infrastructure projects underway. These include fiber-optic networks designed to link administrative functions and services in areas such as tax collection ("Golden Tax"), customs administration ("Golden Customs" or "Golden Gate"), banking services ("Golden Card"), health and medicine ("Golden Health"), and, as the backbone of the system, a nationwide government economic information network called the "Golden Bridge." Collectively, these programs are meant to form China's information superhighway.[51]

Although conceived originally as a means of enhancing central authority, the Golden Projects have had the effect of increasing competition. As the communications networks grew, so did the potential for new applications and the need for increased capacity. China's own telecom providers have since multiplied, and foreign telecom providers now compete to provide much of the necessary hardware and software for these national, provincial, and local networks (foreign telecom firms are still forbidden to operate telecom networks due to PRC security concerns). Consequently, the PRC is an increasingly networked society. Internet cafés now litter China's urban centers, e-commerce has taken hold, and as of July 2001, China topped the list as the world's largest cellular phone market.[52]

More importantly, Chinese leaders have identified information communications technologies (ICTs)—the fastest-growing segment of

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[51] Ibid. 4–5. See also John Ure, "China's Telecommunications and IT: Planning *and* the WTO?," Working Paper (Hong Kong: University of Hong Kong, 2002).

[52] MFC Insight, "China's High-Technology Market" (July 2002).

the Chinese economy from 1996–2000—as the main engine for future growth.[53] The stated goal is to achieve national "Informatization," or the expansion of high-tech communications infrastructure and applications as the foundation for rapid growth in all sectors of the economy. The Golden Projects, originally intended to be completed by 2003, continue to play a central role in this endeavor. Moreover, the current Tenth Five-Year Plan (2001–2005) outlines very ambitious goals for ICT development, which Chinese leaders view as the primary means by which the PRC will be able to "leapfrog" in high-tech capabilities. In late 2001, Jiang Zemin reportedly called this effort of "profound and revolutionary importance," echoing the rallying cries for modernization characteristic of earlier decades.[54]

China's Defense Industrial Reforms Parallel Civilian S&T Modernization Efforts

In addition to the many S&T reforms taking place in the civilian sector, another important and long-term modernization effort was underway during the reform era in China's defense industry. In many ways this paralleled improvements made to the civilian S&T system. In the late 1970s, Deng Xiaoping also announced a new direction for China's Third Front defense industries, emphasizing structural and policy reforms intended to result in more commercially viable enterprises and products. Known as the "16 Character Policy," it translates as:

> Combine the military with the civilian (*junmin jiehe*);
> Combine war with peace (*pingzhan jiehe*);
> Give priority to weaponry (*junpin youxian*);
> Let the civil support the military (*yimin yangjun*).[55]

This "two combinings" strategy promoted defense conversion coupled with defense reversion—a strategy by which China's defense

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[53] Shanthi Kalathil and Taylor C. Boas, "Wired for Modernization in China," Chapter 2 in *Open Networks, Closed Regimes: The Impact of the Internet of Authoritarian Regimes* (Washington, DC: Carnegie Endowment for International Peace, 2002). This report examines the darker implications of nationwide networking.

[54] "President Urges Faster Development of Information Technology," *Renmin Ribao* (*People's Daily*) (December 28, 2001).

[55] For thoughtful discussion on the meaning and implications of this policy, see "New Defense S&T Strategy to Emphasize Technology Transfer to Civilian Use," *China Military Science* (*Zhongguo Junshi Kexue*), no. 3 (August 20, 1995), 131–136; John Frankenstein, "China's Defense Industry Conversion: A Strategic Overview," Chapter One in Joern Brommelhoerster and John Frankenstein, eds., *Mixed Motives, Uncertain Outcomes: Defense Conversion in China* (Boulder, Colo: Lynne Reinner, 1997), 3–34; and Paul Humes Folta, *From Swords to Ploughshares: Defense Industry Reform in the PRC* (Boulder, Colo: Westview Press, 1992).

industries would produce more commercial goods in "spin-off" production while also utilizing more commercial innovations in military, or "spin-on," production. As a result, many defense production lines have been converted to commercial production, and the military became more involved in business ventures throughout China (some very successfully). While the People's Liberation Army (PLA) has since been ordered to divest of its commercial investments, the overall "two-combinings" strategy continues to guide China's defense industrial modernization efforts.[56]

This fundamental reform in the defense industries' orientation resulted in significant institutional reforms. In 1982, the Commission on Science, Technology, and Industry for National Defense (COSTIND) was established to coordinate and oversee these processes, with the objective of modernizing the defense industries to better serve China's military. To achieve this objective, COSTIND was given a bureaucratic foothold in both the military and civilian chain of command. But, by 1998, this model had proved bureaucratically and politically problematic, and COSTIND was split in two, with the newly created General Armament Department (GAD) primarily overseeing the military defense industrial side (answerable to China's military hierarchy) and a newly re-organized COSTIND overseeing China's civilian research efforts (and answerable to the civilian State Council). It was also in 1998 that China's leaders ordered the PLA to divest of its many commercial enterprises.[57]

At present, PRC policymakers continue to struggle to develop a more modern, efficient, and productive defense industry. China's defense-related S&T enterprises, research institutes, and personnel are being re-organized and their efforts re-directed toward more commercially viable endeavors, similar to the reforms made to the civilian S&T sector. While China continues to aim for a self-reliant defense industry, it appears that progress made in this sector of the economy —beyond certain "pockets of excellence"— trails by a considerable degree reforms made to the civilian sector.[58]

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[56] Bates Gill and Lonnie Henley, "China and the Revolution in Military Affairs" (US Army War College: May 20, 1996), available online at http://www.carlisle.army.mil/ssi/pubs/1996/chinarma/chinarma.pdf.

[57] See Chapter Six, "Defense Industries and Weapons Procurement," in David Shambaugh, *Modernizing China's Military: Progress, Problems, and Prospects* (Berkeley, CA: University of California Press, 2002), 225–283.

[58] In describing next steps in advancing the defense sector, China's latest *Defense White Paper* suggests the challenge that lies ahead: "China's defense-related science, technology and industry endeavors to establish and

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China's market-oriented S&T reforms described in the latter section continue into the present day. The national S&T plans and other reform measures described above are being implemented throughout China, with a particular emphasis now being placed on developing China's Western provinces. What distinguishes this latter, post-1997 period, however, is the impact that the global economy has had on these efforts—for good and ill.

Globalization has only enhanced China's market potential, attracting more foreign direct investment than ever before. The PRC is no doubt reaping enormous benefits from this inflow of capital and the technological know-how that typically accompanies high-tech R&D and investments. In fact, foreign investment in China has begun to shift away from primarily labor-intensive industries toward higher value-added manufacturing and high-tech industry sectors.[59] Moreover, the source of foreign investment in China has shifted from mostly small- and medium-sized enterprises to larger-sized investments by multinational corporations, many of whom provide technology-related offsets as part of these investments.[60] At the same time, however, China has become more vulnerable to global influences. Beginning with the onset of the Asian Financial Crisis in 1997 through the more recent slump in the information industry, China's leaders have gained a much fuller appreciation of the risks as well as the rewards from expanded international interdependence. As a new member of the WTO, China's interdependence will only grow, perhaps substantially.

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perfect an organizational system and an operational mechanism tailored to the needs of national defense building and the socialist market economy. It encourages a specialized division of labor, gradually forms a new multi-tiered cooperative system of principal weaponry contractors, sub-contractors and suppliers of parts and components. It also presses forward with the strategic reorganization of military industrial enterprises and institutions, optimizes the allocation of resources, develops core industries, and gradually forms a batch of internationally competitive conglomerates. It makes efforts to deepen the reform of military industrial enterprises, establish a modern enterprise system, and push forward the diversification of investors of the enterprises and transformation of operational mechanisms so as to enable these enterprises to turn into market competitors operating independently and responsible for their own profits or losses." Information Office of the State Council, *China's National Defense in 2002* (December 9, 2002), available online at http://www.china.org.cn/e-white/20021209/.

[59] Yasheng Huang, *Selling China: Foreign Direct Investment During the Reform Era* (New York, NY: Cambridge University Press, 2003), cited in a briefing before the Carnegie Endowment for International Peace (January 16, 2003).

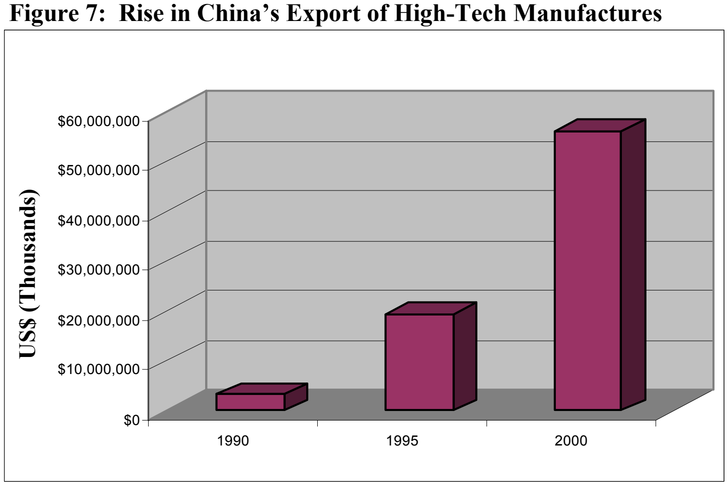
[60] Wang Wei, "China's Internationalization and WTO Entry: Impact on East Asia," briefing before the Joint Symposium on Economic Partnership between ASEAN, Japan, and China: Opportunities and Challenges" (March 25, 2002).

Having long accepted an open door approach to modernization and its inherent risks, it is difficult to imagine a major policy reversal by Beijing. China's new leader, President Hu Jintao, has signaled his commitment to high-tech development as the engine for China's future growth. Indeed, one of the lessons Beijing took from the Asian Financial Crisis was to forsake the export-led growth model adopted by China's neighbors and to concentrate instead on economic development through expanding growth in high-tech industries. Foreign high-tech investment is an integral part of this strategy, as are the hundreds of foreign high-tech R&D centers now cropping up in Chinese cities. While there is continuing interest in acquiring technology hardware, Chinese officials realize that it is the "software"—including R&D—that will prove decisive in achieving China's high-tech modernization goals.

Indicators of Where the PRC Stands Now

After nearly 20 years of implementing market-driven reforms to modernize its S&T system, how far has China actually come? Statistics and other indicators show that the results thus far have been mixed.

Figure 7: Rise in China's Export of High-Tech Manufactures

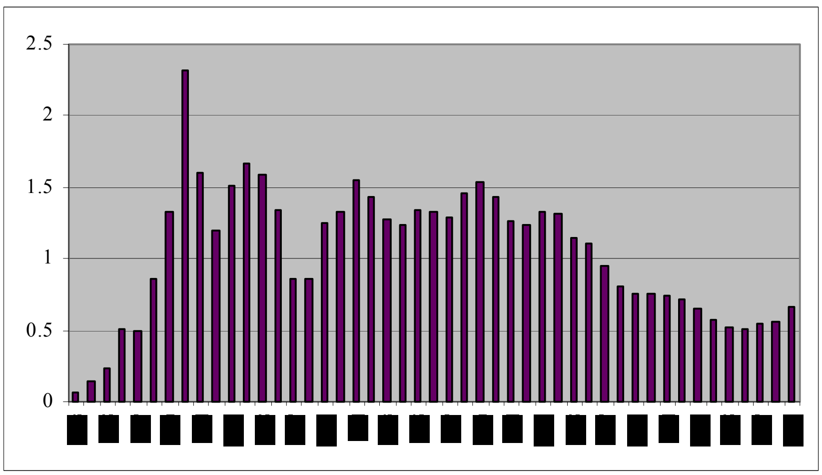


Source: United Nations Conference on Trade and Development (UNCTAD), "International Trade in High-Technology Manufactured Products," *Science & Technology for Development Network*, accessed online (December 6, 2002).

Overall, the PRC economy is becoming more technologically advanced, as indicated by the growing share of Chinese exports classified as "high-tech," indicated in Figure 7 above. According to

World Bank data, 18.6 percent of China's manufactured exports are considered high-tech.[61] Much of this, however, is contributed by foreign-invested enterprises, which still produce nearly 50 percent of China's total exports (down from about 80 percent in 1995). In part by design, China remains heavily dependent on foreign technology imports, with a high-tech trade deficit in 2000 of RMB 15.5 billion (US$1.9 billion).[62] Nonetheless, China's share of the global high-tech market is growing, having reached nearly three percent of global high-tech production by 1998 (nearly matching South Korea's share of 3.1 percent).[63]

Figure 8: PRC S&T Research Expenditures as a Percent of GDP
(1953–1999)



Source: National Bureau of Statistics of China, *China Statistical Yearbook* (2001), Table 3-1: Gross Domestic Product and Table 8-10: Government Expenditure on Scientific Research.

Developments in the computer and telecommunications industries generally reflect these trends. Whereas in the early 1980s China's production, imports, and exports of computer and office machinery were negligible, the PRC has since become Asia's second-largest IT market

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[61] World Bank, "China Data Profile," *World Development Indicators Database* (Washington, DC: The World Bank Group, April 2002).

[62] Deh-I Hsiung, 7.

[63] In comparison, the United States produced 36 percent of the world's high-tech goods, while Japan produced over 20 percent. NSB, *S&EI—2002*, Appendix Table 6.1.

and ranks just behind the United States in global exports of computer hardware. China's exports of computer-related goods in 1998 exceeded imports by a good margin ($10,925 million in exports versus $7,967.1 million in imports), contributing to the PRC becoming the United States' largest foreign supplier of computer equipment in 2002. Much of the growth in this sector, however, reflects increased production and assembly in China of foreign components.[64]

In telecommunications equipment, China's production figures for 1998 are considerably higher ($40,608.2 million) compared to computer and office machinery, which amounted to $7,529.1 million in output. But so were China's imports of telecommunication equipment, which in 1998 were nearly three-times higher ($20,587 million) than imports of computer-related items ($7,967.1 million). Similarly, China's 1998 exports of telecommunications equipment exceeded those in the computer sector, reaching nearly $14 billion overall. By 2001, the United States alone was importing $3.2 billion worth of telecommunications-related equipment from China, indicating China's growing competitive capabilities in this sector. According to the US Commerce Department's latest assessment, "Chinese [telecom] manufacturers now compete more vigorously with foreign companies not only in the Chinese market, but also in third-country markets."[65]

In terms of government funding for science and technology, China's direct spending on S&T has declined over the last five decades (as shown in Figure 8). The data, however, do not account for the growing influence of supplemental sources of S&T funding (e.g., bank loans and other grants, foreign investment, and venture capital) that Chinese policymakers have promoted throughout the post-1985 reform era. In 2001, Beijing appropriated RMB 70.3 billion (US$8.5 billion) to S&T while RMB 258.9 billion "were raised" (it is unclear by whom), with the latter figure representing a 10 percent increase over the year 2000.[66]

The PRC's spending on R&D, by contrast, has increased steadily, particularly over the last decade. Between 1995 and 2000, China's gross expenditure on R&D (GERD) more than doubled—from RMB 34.9

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[64] See International Trade Administration, *ExportIT China: Telecommunications and Information Technology Market Opportunities for Small and Medium-Sized Enterprises* (Washington, DC: US Department of Commerce, April 2003); NSB, S&EI—2002, Appendix Table 6.1 (calculated in 1997 dollars).

[65] Ibid.

[66] National Bureau of Statistics, "The Science and Technology Input Entered a Swift Growth Period in China" (November 15, 2002).

billion to RMB 89.6 billion (US$10.8 billion)—thanks to a near or more than 20 percent annual increase in three out of the six years. This growth reflects a clear commitment to science and technology development by China's leadership. By the year 2000, R&D spending had reached one percent of GDP (although this fell short of Beijing's five-year goal of 1.5 percent). While this level is in line with, if not higher than, many developing nations, it is quite far below the levels of R&D spending by industrial countries, which averages 2–2.5 percent.[67] However, it is interesting to note that China's one percent of GDP is nearly comparable to that of the United States back in the early 1950s, when US R&D as a percent of GDP came to 1.36 percent.[68] Having failed to reach a GERD/GDP rate of 1.5 percent by 2000, Beijing has made this the goal for the current five-year plan ending in 2005.

The large majority of China's R&D spending is allocated to technology development (as shown in Table 2). More state funds are being provided for this purpose as Beijing continues to pressure scientists, researchers, and engineers—who typically conduct basic and applied research—to come up with funding from sources other than the state. This does not imply neglect of basic or applied R&D, however, as China's leading scientific institutions—the NSFC and CAS—have enjoyed large increases in their R&D budgets during the late 1990s.[69]

Table 2: PRC Spending on Research and Development

	State R&D Expenditures (RMB Billion)	**Percent of Total R&D Spending**
Basic Research	5.2	5%
Applied Research	17.6	16.9%
Technology Development	81.4	78.1%

Source: National Bureau of Statistics, "The Science and Technology Input Entered a Swift Growth Period in China" (November 15, 2002).

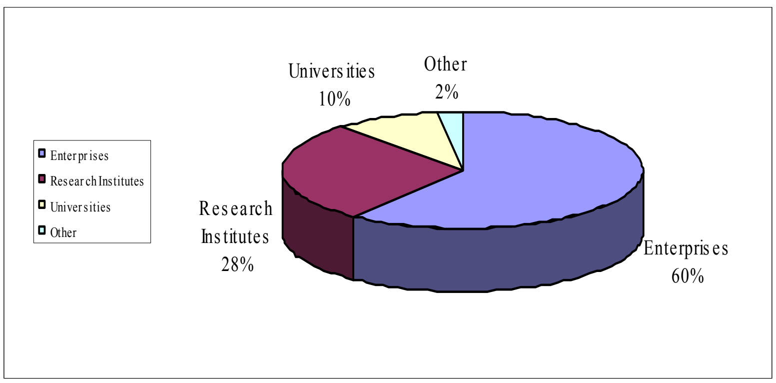
[67] Deh-I Hsiung, 10–11; Brandon Shackelford, "Slowing R&D Growth Expected in 2002," *Science Resource Statistics*, NSF-30-037 (Washington, DC: National Science Foundation, December 2002).

[68] This is the figure for 1953, the first year for which the National Science Foundation has data. NSB, *S&EI—2002*, 4–18.

[69] Deh-I Hsiung, 5 and 24.

Performance of R&D in China also has increased, as calculated by research funds expended by: 1) government research institutes; 2) state-owned and private enterprises; and 3) institutes for higher learning (mainly universities). As Figure 9 shows, China is not unlike other countries today in that most R&D is performed by industry. This represents a marked improvement from the mid-1990s when only about 30 percent of R&D work in China was performed by enterprises (the remainder was largely conducted by often inefficient state-run institutes). Today, 60 percent of R&D in China is performed by enterprises, bringing the PRC more in line with industrialized economies.[70] Interestingly, however, while all sectors have increased R&D performance, China's universities have demonstrated the largest percent increase from the previous year (2000), increasing R&D expenditures by more than 30 percent.

Figure 9: R&D Performance by Sector (2001)



Source: National Bureau of Statistics, "The Science and Technology Input Entered Into a Swift Growth Period in China" (November 15, 2002).

The biggest spenders in 2001 on R&D among Chinese municipal or provincial authorities (each spending RMB 5 billion or more) included Beijing, Shanghai, and Guangdong, Jiangsu, Shandong, Sichuan, Liaoning, and Shanxi Provinces. These expenditures represented over three-quarters of total PRC spending on R&D for 2001.[71] Despite rising

[70] *Science and Education for a Prosperous China*, excerpted in "Chinese Challenges in Absorbing and Producing New Technologies," A Report by the US Embassy Beijing (December 1996).

[71] The year-on-year increase (2000–2001) in R&D expenditures for enterprises and research institutes were 17.3 percent and 11.7 percent, respectively. National Bureau of Statistics, "The Science and Technology Input Entered Into a Swift Growth Period in China" (November 15, 2002).

R&D spending in all sectors of China's economy, the level of R&D intensity (the ratio of R&D expenditures to sales) remains modest at around 0.5 percent, a relatively low level in comparison to industrialized countries (which range from one to three percent of GDP).[72] For high-tech industries, the divide is much wider, as shown in Figure 10.

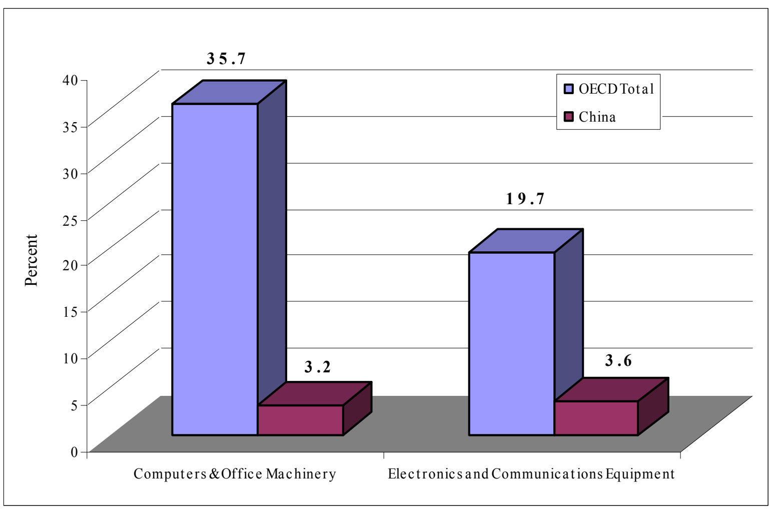
Table 3: Asian Scientific Citations (1997-2001)*

	PRC	ROC	South Korea	India
Overall Share	3.24%	1.27%	1.56%	2.17%
Co-authored Citations	114,894	45,204	55,329	76,970

* South Korea figures are 1995–1999 only.

Source: "SCI-Bytes: What's New in Research," *ISI Essential Science Indicators*, various issues (August–December 2002).

Figure 10: R&D Intensity in High-Tech Sectors (Late 1990s)



Source: Adapted from OECD, "Figure 6: R&D Intensity in High-Technology Sectors, Late 1990s," in *Science, Technology and Industry Outlook 2002*—Highlights (Paris, France: OECD, 2003), 12. Note: OECD figures are for 1997; China figures are for 1999.

[72] OECD, *Science, Technology, & Industry Outlook 2002* (Paris, France: OECD, 2002).

A number of other S&T indicators show that China is making steady progress in its high-tech pursuits. For instance, by the year 2000, China ranked eighth in the world in terms of the number of scientific papers contributed by Chinese authors (with a total of 30,499 papers representing 3.15 percent of the world total), according to the Science Citation Index.[73] This is a considerable improvement from just five years before, when China ranked only 15th in the world.[74] While the PRC's international scientific citations are well below the contributions made by more developed economies (in fact, they are below the world average in every category), the PRC out-ranks and out-produces neighboring economies (see Table 3). Moreover, the PRC ranks high in the number of engineering papers, reaching the third top spot in world rankings in 1999 (up from fifth place the year before).[75]

The number of Chinese patent applications and certifications also show continued steady growth, although most are not for inventions but for designs or utility models (which is not surprising given the government's emphasis on funding technology development and applied research activities). Between 1995 and 2000, the total number of patent applications certified in China more than doubled, and approved patents for inventions grew more than three-fold.[76] But the rise in PRC patents overall is in part due to foreign applications, which have been outpacing domestic patent applications for inventions in recent years.[77] This situation differs substantially from the mid-1990s, when domestic applicants dominated PRC patent statistics.[78] Today, patents granted to foreign applicants outnumber Chinese patents certified for inventions as well as patents in high-tech sectors, although PRC firms still dominate patent applications and certifications for utility models. Despite these gains, which reflect growing confidence in PRC patent protections, enforcement of intellectual property rights in China remains a serious

[73] Deh-I Hsiung, 15.

[74] Suttmeier and Cao, 7.

[75] Deh-I Hsiung, 16.

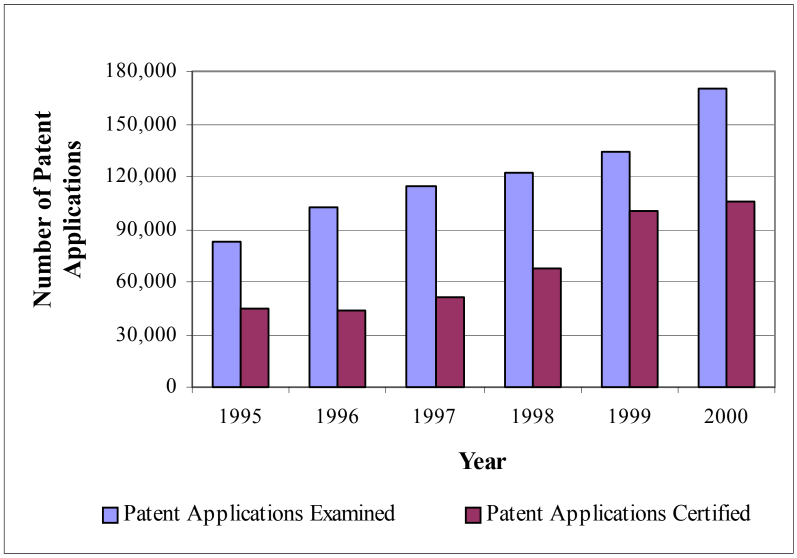
[76] Deh-I Hsiung, 17; OECD, 11; World Intellectual Property Organization (WIPO), *Industrial Property Statistics Publication B, Part I, Extracts for China*, available online at http://www.wipo.int/ipstats/en/index.html. The latter data do not recognize design patents.

[77] WIPO, *Industrial Property Statistics Publication B, Part I, Extracts for China*; Steven J. Frank and Yin Philip Zhang, "Year of the Patent," *IEEE Spectrum* (January 2003). The article's authors contend that changes to China's patent laws—which now allow pre-sale legal action in patent infringement cases—are a key factor in the increase in foreign patent applications in recent years.

[78] WIPO, *Industrial Property Statistics Publication B, Part I, Extracts for China*, annual data for 1994–2000.

concern for both domestic and foreign high-tech investors. As noted by the American Chamber of Commerce in its most recent *2002 White Paper*: "Investments in R&D cannot be made without a reasonable assurance that the resulting intellectual property will be protected long enough to earn an economic return."[79]

Figure 11: PRC Patent Applications and Certifications (1985–2000)



Source: National Bureau of Statistics, *China Statistical Yearbook* (2001), Table 20–38: Basic Statistics on National Scientific and Technological Activities and Table 20–55: Three Types of Patent Applications Examined.

Finally, China's national technology infrastructure continues to expand. The number of telephones (fixed and mobile) and personal computers per thousand persons in the PRC more than doubled from 1997 to 2000. During this same period, the number of Internet users in China multiplied more than 50 times—from 400,000 to 22.5 million.[80] While this still only represents a fraction of China's total population, the PRC has more mobile phone users (at present more than 170 million) and

[79] The American Chamber of Commerce–People's Republic of China, *2002 White Paper: American Business in China* (Beijing: The American Chamber of Commerce–PRC, 2002), 40.

[80] World Bank, "China Data Profile," *World Development Indicators Database* (Washington, DC: The World Bank Group, April 2002).

fixed line telephone services (an estimated 200 million) than any country in the world.[81]

What Does It All Mean?

As the above measures demonstrate, the PRC has made impressive gains in some key scientific and technological areas. Overall, the trend line is positive. Nevertheless, when compared to world standards, China's achievements and high-tech capabilities do not yet match those of industrialized nations, and it is likely to be some time before they do.

When comparing Chinese S&T capabilities with other countries, however, it is necessary to look beyond traditional comparative statistics.[82] For example, any per capita-based indicator will almost automatically place China low on the scale given the Mainland's 1.3 billion-sized population. While usually a good measure of S&T capacity, such a calculation applied to the PRC would likely underestimate China's true potential, particularly over the near-term. Although it is essential to consider a country's entire population in analyzing S&T trends, any visitor to the Mainland quickly realizes that there are two distinct economies in China: the mainly urban and increasingly advanced economies along the coastal areas and the vast rural, mostly agricultural economy to the West. Therefore, just as it would be unwise to calculate potential business prospects in China by factoring in the entire population of 1.3 billion people (although this occurs with alarming frequency), it would be equally unwise to rely solely on per capita data to measure China's potential high-tech capabilities. So, while the vast majority of Chinese do not have access to the Internet, for instance, there are many who do, and they can be found in China's newest and most technologically advanced high-tech development zones, science parks, and newly emerging high-tech enterprises. Thus, to measure the pace of China's technological ascent, one must first look to these more advanced assets and their implications in order to assess how long it will take the rest of China to catch up.

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[81] David Snodgrass, *China Country Commercial Guide FY2003,* no. 106626 (Beijing: US Embassy, 2002), 21.

[82] Chinese statistical data are notoriously inaccurate, making any determination of trends or comparative analyses rough indications of reality at best. See, for example, Thomas G. Rawski, "China by the Numbers: How Reform Affected Chinese Economic Statistics" (revised December 20, 2000), available online at http://www.pitt.edu/~tgrawski/papers2000/REVD00.HTM; and "What's Happening to China's GDP Statistics?," *China Economic Review*, vol. 12, no. 4 (December 2001): 347–354, available online at http://www.pitt.edu/~tgrawski/papers2001/gdp912f.pdf.

Another difficulty in assessing high-tech indicators vis-à-vis China is the pace of economic and technological growth, which is impressive by world standards. But, as indicated earlier, some statistics show not only improvement but a trend reversal from the mid-1990s, which might indicate substantial progress. Alternatively, the data might reflect other, less obvious underlying dynamics such as changes in China's investment or legal policies that allow new foreign participation in these sectors. Such shifts likely are not due to a singular cause.[83] Nevertheless, a number of the indicators cited above show substantial year-on-year increases in S&T inputs, output, and capabilities. While one cannot expect this to continue indefinitely, the potential trajectory of China's high-tech advancement—if current growth rates are extrapolated out over time—is reason to keep a close eye on the PRC's progress in high-tech areas.

What the data do make clear is China's commitment to becoming a high-tech competitor by any world standard. This is an ambitious undertaking, but Beijing has shown thus far a willingness to expend significant funds and effort toward achieving this objective. As a result, all sectors of China's research and enterprise communities are working to enhance and accelerate China's high-tech growth. More importantly, the different stakeholders—government, research institutes, and enterprises—are working in a comparatively more dynamic and coordinated fashion (at least in the civilian S&T sector) than in the past in order to realize the potential gains from high-tech collaboration.

LOOKING AHEAD: CHINA'S S&T OBJECTIVES FOR THE 21ST CENTURY

As indicated at the beginning of this chapter, China's goal is to be among the world's most competitive high-tech economies, on par technologically—at least in some sectors—with the best in the world, and to achieve this goal sooner rather than later. Currently, China's emphasis is on accelerating high-tech development through "Informatization," a technology development program that encompasses all sectors of China's economy: "informatization is the key in promoting industrial advancement, industrialization, and modernization."

[83] External or political factors also cannot be discounted, since the IT industry boom through the late-1990s as well as China's pending membership in the World Trade Organization had an obviously positive effect on China's own high-tech advancement, at least for a time.

Also according to China's Tenth Five Year Plan, through 2005, Beijing plans to invest over one trillion yuan (or more than US$120 billion) in the information technology industry with the goal of doubling the size of China's IT industry to comprise a full seven percent of the PRC's national GDP. This investment, it is hoped, will put 40 million PCs in China online with 200 million Internet subscribers and provide communications services for nearly a quarter of the world's fixed and wireless subscribers, among other aspirations.[84] Though clearly an optimistic view of the future, this bold plan makes clear China's intent to become a global competitor in these critical technologies.

As an important part of this strategy, Chinese officials have placed an even greater emphasis on promoting high-tech skills and education, which the Chinese public seems eager to embrace. State-funded training (and, in many cases, re-training) centers are appearing in numerous Chinese cities. In addition, national and local leaders have instituted new incentive programs targeted at rewarding leading scientists and research institutes for producing high-tech results and provided more state funding for international scientific and technological exchanges.

Chinese officials also have adopted new policies to entice the tens of thousands of highly educated and skilled Chinese who are living and studying abroad to return to the Mainland where many will enjoy comparable salaries, Western-style housing, and work in modern office complexes located in high-tech science parks modeled on Silicon Valley. A growing number are beginning to take up these offers, particularly in the aftermath of the IT industry bubble and declining job opportunities available in Silicon Valley. Many returnees have accepted positions in high-tech enterprises or research institutes, while others have tried establishing their own start-up enterprises in China (usually with some financial support from the central or local government).[85] These efforts are particularly important given China's aging scientific community—those educated prior to the Cultural Revolution who are now retiring in large numbers.[86] Chinese officials recognize that the combination of this

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[84] "PRC Official: China's IT Investment to Top 1 Trillion Yuan Over 5 Years," *Xinhua*, in FBIS-CHI-2001-0926 (September 26, 2001). To coordinate policy implementation across several ministries, Chinese leaders established in August 2001 the State Council Informatization Office (SCITO), with a Steering Group chaired by China's premier. International Trade Administration, *ExportIT China: Telecommunications and Information Technology Market Opportunities for Small and Medium-Sized Enterprises* (Washington, DC: US Department of Commerce, April 2003).

[85] Beijing's Zhongguancun high-tech zone claims to host over 500 companies started by returning Chinese entrepreneurs. "China Tipped to Become World Hi-Tech Center," *Renmin Ribao* (June 2002).

[86] The majority of CAS researchers are under 45 years of age. Deh-I Hsiung, 6.

demographic reality with a continued “brain drain” to the West could seriously hinder continued progress in S&T development. For this reason, as described in the following chapter, one of the key roles expected of many foreign R&D centers is to train Chinese workers in both high-tech skills and Western management concepts and practices.

In the meantime, China’s Minister of Science and Technology has identified 12 key technologies that will comprise the PRC’s S&T focus during the period of the Tenth Five Year Plan (2001–2005).[87] These are:

- Super scale integrated circuits and computer software
- Information security systems
- E-administration and e-finance
- Functional gene-chips and bio-chips
- Electric automobiles
- Magnetic levitation trains
- New medicines and modernization of traditional Chinese medicines production
- Intensive processing of farm produce
- Dairy product manufacturing
- Food security
- Water-conservation farming and water pollution control
- Establishment of key technical standards.

It is in these areas that the PRC will make a push to achieve parity with (or surpass) the industrialized nations’ technological capabilities. Foreign investment is intended to play a critical role in China’s high-tech development strategy, including increasing levels of investment in high-tech R&D. Chapter Four looks in detail at the emergence and evolution of foreign-sponsored high-tech R&D programs in China, with a focus on the growing numbers of R&D centers appearing in the computer and telecom industries.

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[87] “China to Focus 12 Key Technologies, Ready for Int'l Sci-tech Competition,” *Renmin Ribao* (January 10, 2002).

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The Emergence and Evolution of High-Tech R&D in China: A Study of Two Industries

"R&D in China is more 'D' than 'R'"[1]

Foreign high-tech R&D first emerged on the Chinese Mainland in the mid-1990s. Since then, this trend has evolved much the same way the global R&D trend has unfolded in other parts of the world. In particular, the computer and telecommunications industries are driving R&D investment in the PRC. Both industries are highly dependent on R&D for innovation, have rapid production cycles, and are increasingly international in scope. Both also have entered the China market in large numbers. This chapter explores the emergence and evolution of high-tech R&D in the PRC with a focus on these two industry sectors.[2]

US computer companies first entered China some time ago. In 1985, IBM became one of the first US computer companies to set up shop on the Mainland.[3] Hewlett-Packard (HP) also entered the China market that same year, establishing the first official Sino-foreign, high-tech joint venture. Since then (with a considerable pause following Tiananmen), these multinationals have been joined by numerous other high-tech companies from around the world who are drawn to the Mainland with the dream of capturing a piece of this dynamic and sizeable market.

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[1] An oft-heard statement by foreign R&D managers in China.

[2] Although other high-tech industry sectors have entered China to conduct some type of R&D and also rely heavily on international R&D networks to expand scientific and innovative capacity (particularly the pharmaceutical and biotechnology industries, as well as the auto industry and others), the information technology industries share important dynamics and investment incentives that are quite unlike those that drive other industries. For example, an important reason for conducting communications technology-related R&D abroad is the need for foreign-language programming and services, whereas a key motivation behind conducting pharmaceutical research overseas is the comparatively less restrictive laws and regulations governing experimental research in some developing countries. For this reason, the study was more narrowly defined to encompass only these two, related industry sectors. Also, it should be noted that the findings from this study, given the ICT industry's fast-paced and comparatively mobile nature, might not translate fully to other, more physically grounded or industrialized sectors.

[3] The now-defunct Wang Laboratories started doing business on the Mainland as far back as 1972 and set up its first joint venture in 1986. The description of the negotiations leading up to this JV agreement is strikingly similar to stories heard today. See Office of Technology Assessment, *Technology Transfer to China***,** OTA-ISC-340 (Washington, DC: US Government Printing Office, July 1987), 97–98.

Today, high-tech multinationals from around the world are establishing growing numbers of R&D centers, programs, and labs in China. HP established what is considered by foreign R&D managers to be the first true foreign-sponsored high-tech R&D center in China in the mid-1990s.[4] Similarly, IBM established its China Research Lab in Beijing in 1995 "to focus initially on creating software and applications that are especially relevant to China. . . . [including] digital libraries, speech recognition for Mandarin, machine translation, Chinese language processing, multimedia and the Internet."[5] Often accompanying these R&D programs and other types of investment are various forms of traditional technology transfer such as education and training programs, licensing agreements, contract research, and equipment donations.

But what has motivated foreign multinationals to invest in R&D in China, and how is this activity different from past investment practices and technology transfer activities? The evolution of investment, technology transfers, and foreign-invested R&D in China sheds some light on the impact the growing R&D trend may have on China's development and foreign relations.

RESEARCH AND DEVELOPMENT: THE NEXT STEP IN THE VALUE CHAIN

As the above examples show, technology transfer in some form is not an entirely new phenomenon vis-à-vis the PRC. Not long after their initial investments, IBM and other computer companies also began to establish training centers in China to support their sales programs and for the express purpose of helping to educate and transfer know-how to their Chinese partners. This is a typical form of first-entry activity for high-tech companies investing abroad.

Today's R&D centers represent the next step in the evolution of high-tech investment in China. As described by R&D managers, industry experts, and researchers familiar with the China market as well as global high-tech investment practices, the growth of overseas R&D in China is just the latest of several discrete phases typical of high-tech investment in foreign markets. In this way, the China market is experiencing the same dynamic taking place in other parts of the world

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[4] Author interviews with foreign R&D managers in China (July 2002).

[5] Presently, IBM has five research centers located abroad. These are located in Japan, Switzerland, Israel, India, and China. See "Research History Highlights: History of IBM Research 1945–1996," IBM Research website (www.ibm.com).

due to globalization. In China, R&D represents the latest of four phases in foreign high-tech investment (though all of these phases occur continuously as new investors enter the market):[6]

- *Phase I: Sales, Marketing, Licensing, and Technical Services Support*. This initial phase involves opening a representative or sales office, typically in the capital city or appropriate industry center. The purpose is to establish a presence in the market, to provide executives with a window or "listening post" intended to aid in analyzing the foreign market, government, and industry, and to begin work toward enhancing the company's reputation and name brand recognition. Investors might also set up technical support services for their products sold abroad and license their technology to local vendors. This type of activity was most pronounced in China in the 1980s and early 1990s.

- *Phase II: Manufacturing and Production.* Once a company presence is established, the next typical step is to form an enterprise to begin manufacturing and production. Often this takes the form of a joint venture, whether by regulation or by preference. Frequently it is both, since having a local partner can aid new entrants in navigating a foreign market, bureaucracy, and legal system. At this stage, technology, training, know-how, and equipment are often transferred to the local partner in order to educate local workers in the manufacturing process and to ensure quality production. Foreign investors might also need to make changes to their production process in order to address technological design or other challenges arising from environmental conditions or the state of local infrastructure.

- *Phase III: Product Design, "Localization," and Redevelopment*. At this stage (which often overlaps with the previous phase), R&D in the form of technology development work is generally needed to "tweak" the product or manufacturing process to reflect local tastes, market dynamics, industry regulations, and

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[6] The author is grateful to both the experts interviewed in China (in the summer and fall of 2002) and those attending an informal background briefing held in Washington (spring 2003) for explaining this process and outlining the different phases of high-tech investment.

standards. This activity often benefits from collaboration with Chinese engineers and others who can help to more quickly adapt foreign technology and products to local market conditions. This can also include more sophisticated work such as systems or standards integration and is sometimes conducted for or with third-party clients or customers (such as government ministries or departments and universities). Foreign investors sometimes employ local university researchers on a contract basis to conduct this type of work. All of these activities were evident in the China market by the late 1990s. It is at this stage that foreign R&D centers first appear.

- *Phase IV: R&D.* Over time, foreign investors in the China market and elsewhere must upgrade their product lines in order to keep ahead of the market and remain competitive; the products the company first entered the market to sell have since become outdated. Moreover, as multinationals continue to spread their businesses across the globe, corporate subsidiaries are expected to become more self-sustaining and to contribute more substantially to the company's global enterprise—not only in terms of revenue but also (especially in ICT industries) by contributing innovatively. It is at this stage that foreign R&D centers expand or are consolidated to allow more advanced onsite research and development work; this is what we are now beginning to see in China.

As outlined above, the appearance of high-tech R&D in China is completely understandable as a normal progression of the foreign investment cycle. However, this more generic model misses some important nuances and dynamics that are specific to the China market, as discussed in the following section.

DYNAMICS OF HIGH-TECH INVESTING IN THE CHINA MARKET

Since Deng Xiaoping announced China's "Open Door" policy in the late 1970s, the PRC has welcomed foreign investment, technology, and know-how from all corners of the globe. In particular, it is the world's leading high-tech and Fortune 500 firms that Chinese officials and leading enterprises are most interested in attracting. To date, they have had wondrous success in doing so: 400 of the Fortune 500 have a presence in the China market. For China, the benefit—beyond the obvious inflow of capital—is to learn from the best in the world in order to help the PRC leap ahead in its drive to modernization. In fact, Chinese officials and company CEOs are unabashed in declaring this to be their objective. Given China's market potential and steady stream of investors, others in the region can only envy China's position. At the same time, however, the PRC has already learned the lesson that simply acquiring technology from abroad will not necessarily translate into the technological know-how needed for advanced and long-term civil or military technology development. This is a major reason behind the new emphasis being placed on high-tech R&D—both in China's domestic S&T programs and as a form of foreign investment and technology transfer.

The emphasis on R&D is particularly evident in the computer and telecom industries, which Chinese officials have designated as "pillar industries." For example, China's latest software industry policy (for the period 2002–2005) reportedly seeks "to encourage establishment of Sino-foreign R&D facilities on key software technologies."[7] In the telecom sector as well, foreign investors are encouraged to establish R&D centers but are no longer required to do so. In this and other ways, each industry has adopted development strategies that are similar. But the strategies also differ in important respects given the separate bureaucratic and technological challenges that each industry faces.

A Common Development Strategy: Attracting Multiple Foreign Partners

A main similarity in the development strategies of both the computer and telecom industries in China is an attempt to partner with several leading foreign firms simultaneously as a means of accelerating and broadening technological capabilities. Partnerships involve a full range of activities: from domestic distribution of foreign-made products—a frequent initial form of international collaboration, particularly in the China market where domestic firms have long held sole distribution rights—all the way to collaborative design work. For example, a leading Chinese telecom firm in southern China proudly listed the various types of partnerships the enterprise had developed with more than a dozen separate foreign telecom firms. These ranged from licensed sales and distribution to joint manufacturing plus design and development work.

[7] "New Policies to Invigorate China's Software Industry," *China IT & Telecom Report* (November 29, 2002).

The partnerships were mainly with well-known multinationals, all of whom likely transferred some form of technology, equipment, or know-how that could potentially aid the Chinese partner's efforts to modernize its own enterprise.[8] The operative word here is "potentially," as mere partnerships do not in any way ensure technology absorption on the part of the domestic partner.[9] However, according to the Chinese executive, his company had learned a good deal about modern business practices as a result of partnering with different foreign companies. As in this case, the strategy of establishing multiple technology partnerships has proven to be an effective approach for some Chinese enterprises to quickly develop more advanced capabilities.

But an interesting—and requisite—aspect of this strategy is the seeming ignorance on the part of foreign investors about the multiple strategic alliances some of their venture partners in China have established (until relatively recently, most foreign investment in China took the form of a joint venture). In interviews with foreign MNC representatives in the PRC in 1998, most were surprised when presented with a list of a Chinese company's multiple foreign partners. One reason, as explained by a knowledgeable foreign business executive, was that due diligence conducted on prospective Chinese partners usually only went so far as the Chinese company's own activities—it did not necessarily take into account the prospective partner's myriad other foreign arrangements, whether due to a lack of information, concern, or resources. In other cases, it was not uncommon for Chinese officials to simply suggest to foreign investors what companies would make an appropriate Chinese partner. This practice no doubt aided the state-promoted partner's efforts to develop numerous international technology and other business-related alliances, although partnerships arranged in this fashion were probably less likely to result in serious technology transfers.[10] Yet, alarmed by the long list of foreign competitors with whom his own Chinese partner was affiliated, one foreign corporate executive expressed dismay, wondering out loud whether the partnership was pitting his own company against other foreign competitors via the Chinese joint venture partner's alliance network. His realization also

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[8] Interview with Chinese high-tech enterprise (March 17, 1998).

[9] For many reasons, the partnership may or may not yield a fruitful relationship for either or both parties. At the same time, the possibility of substantial technology transfer exists and can accelerate development of new local competitors.

[10] Interview, Hong Kong (March 1998). This type of pressure appears to have abated or, at least, is not quite as open as it was a few years ago.

raised questions about the Chinese partner's capacity to advance technologically perhaps more quickly than the executive had initially assumed.[11]

Nonetheless, this strategy is probably less effective today than it was just a few years ago. The reason is that multiple strategic partnerships are likely fewer in number now due to two important factors: 1) the expanding list of potential PRC industry partners; and 2) the relatively more proprietary nature of R&D work, particularly when compared to sales and marketing activities, for instance. R&D is simply not as conducive to multiple partnerships as other types of investment.

Unlike in the early 1990s, when there were often only a few leading Chinese computer or telecom enterprises with whom a foreign company could—or would wish to—partner, today there are a growing number of competitive Chinese enterprises to consider. As these industries continue to develop on the Mainland, there will be more competition and a greater number of partners from which to choose, thereby diminishing, in all likelihood, the concentration of foreign partnerships with any one Chinese enterprise. Moreover, due mainly to WTO-related reforms, foreign companies are no longer required to have Chinese venture partners to invest in most high-tech industries. As a result, many investors today are opting to establish wholly foreign-owned enterprises (WFOE).[12] This is also the strategy many foreign investors are following in setting up R&D facilities in China, which more and more are wholly foreign-owned and managed.

Still, the strategy of attracting multiple foreign partners has paid off for a number of Chinese enterprises, particularly some of China's most successful "new technology enterprises," or NTEs. For example, the strategy played a prominent role in the development and rapid rise of four of China's most successful high-tech enterprises: Legend, Stone, Founder, and Great Wall. Through partnerships with multiple MNCs, these "star" enterprises not only prospered, but also learned a great deal about modern manufacturing, production and enterprise management, as

[11] Interview with US corporate executive, Hong Kong (March 1998).

[12] The shift in preference from mostly joint ventures to wholly foreign-owned enterprises emerged for the first time in 1998, although WFOEs make up only an estimated 20 percent of foreign-invested enterprises. WFOEs are required to import or produce advanced technologies or to be geared mainly toward exporting. A key exception remains telecom services operation, which remains closed to foreign investment except through joint ventures but will be opened up in phases over the next several years under China's WTO commitments. See "Unhappy Marriages Leave Foreigners Opting to Go Solo," *South China Morning Post* (March 17, 1998), 4; and David Snodgrass, *China Country Commercial Guide FY2003,* no. 106626 (Beijing: US Embassy, 2002), 11.

well as marketing and financing—all areas where Mainland firms typically have weak, if any, competitive capabilities.[13] While foreign investors certainly have benefited from partnering with these Chinese enterprises, it is possible—if not likely—that the Chinese partner gained considerably more from engaging in partnerships with multiple foreign high-tech firms at once. This particularly is the case with R&D. As a recent US government report on the globalization of R&D notes, "Although US R&D abroad may result in technology transfer back to the US parent company, most of the direct benefits of R&D spending abroad—employment and spillovers—appear to be localized in other countries."[14]

A New Dimension to An Old Strategy: Competition Among Foreign R&D Investors

Another strategy for attracting foreign partners and technologies that is common across China's computer and telecom industries (as well as other sectors) is to actively play one foreign investor against another. The best example of this exists in the aerospace industry, where Boeing and Airbus continuously battle one another for a greater share of the China market. For their part, PRC officials are in an envious position that often allows them to hold out for more technology and other types of offset arrangements that competing foreign firms might offer. In this, the PRC is no different than any other country, except for the fact that China is considered by many industry experts to be absolutely essential to the aerospace and other industries' future growth. So, while not exclusive to the China market, this dynamic appears to pay repeated dividends. For example, the competition in the late 1990s among foreign auto companies to establish what was billed as the last Sino-foreign automotive joint venture to be approved for several years in Shanghai led to an unprecedented level of foreign investment and technology transfer commitments—including a joint R&D center—with General Motors ultimately winning the bid.[15]

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[13] Qiwen Lu, *China's Leap Into the Information Age: Innovation and Organization in the Computer Industry* (Oxford: Oxford University Press, 2000), 185–86.

[14] Dalton, et al., *Globalizing Industry R&D* (Washington, DC: US Department of Commerce, 1999), 33.

[15] "Testing GM's Shock Absorbers," *The Economist* (May 1, 1999). See also "GM Links Universities in Shanghai, Michigan to Carry Out Research for GM Ventures in China," *Automotive Intelligence News* (October 29, 2000).

At the same time, though less publicized (if revealed at all), there are some counterexamples of MNCs stepping away from the negotiating table and, on occasion, away from the market.[16] This, of course, does not happen very often, but it does occur. Such a stand is to be admired even more given the prospective long-term costs this could mean for a company's opportunities to invest in the China market down the road.[17] Moreover, while the constant push and pull over technology or other investment-related offset arrangements are a factor in business negotiations all around the world, the dynamic often appears magnified in the China market.

In recent years, the competition for market share and access among foreign investors in China has expanded to encompass R&D programs. As the number of foreign-invested R&D centers in the PRC has grown, so has the interest in, and in some cases pressure on, other foreign companies to establish similar programs, particularly latecomers to the market. As the number of foreign investors who have one or more R&D center in China has grown, those who do not have such investments have come under increasing internal and external pressure to invest in R&D. For example, Volkswagen is a long-time and successful investor in China but became conspicuous in the late 1990s for lacking a China R&D center (a situation that has since been rectified).

Interestingly, the pressure to invest in R&D is the result of inter-firm rivalry as much or more than Chinese government policies that reward R&D investment.[18] The latter can include lower tax rates and other financial incentives for foreign firms registered as R&D centers, providing even more motivation to establish something termed "R&D," whether in fact it entails genuine research and development work or not.

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[16] Ironically, in the case of IBM, the company's refusal to transfer its advanced technologies nonetheless might have led to a revelation that helped spur on China's own computer industry development. In Qiwen Lu's study of leading Chinese high-tech enterprises, he quotes the deputy bureau chief of China's Computer Industry Administration (and later president of China Great Wall Computer Company) as saying that, through these failed negotiations, "This way we learned how IBM organized its business. It was the first time we learned first-hand that there were different ways of organizing a business." Quoted in Qiwen Lu, 151–153.

[17] Interview with a knowledgeable American representative of a large US MNC (March 4, 1998).

[18] This new R&D-competitive dynamic was cited in several interviews with foreign managers of R&D centers in China in 2002. Prior to China's accession to the WTO, foreign investors were regularly pressured to transfer technology in return for market access. Since becoming a WTO member, however, the PRC has formally and specifically committed not to force on foreign investors requirements for technology transfer, local content requirements, export performance quotas, and other conditions. See Kathleen Walsh, "US Export Controls and Commercial Technology Transfers to China," Testimony before the US-China Security Review Commission, Hearing on Export Controls and China (January 7, 2002; and US Trade Representative, *2002 Report to Congress on China's WTO Compliance* (Washington, DC: US Government Printing Office, 2002), 11.

These dynamics account, at least in part, for what appears to be a rapid rise in the number of foreign-invested R&D centers appearing in the China market (as discussed in more detail later in this chapter).

Finally, the underlying rationale behind R&D investments (or other types of foreign investment) matters in determining how substantial foreign-invested R&D is as a form of technology transfer. For instance, if the objective is primarily to appease Chinese regulators, the likelihood of substantial technology transfer taking place is significantly less than if the foreign investor is truly interested in investing in and conducting R&D abroad. The former was the case in many of the early foreign R&D investments in the computer, telecom, and other industry sectors where it was required through official (or unofficial) policy, or was the result of competitive pressures. Consequently, much of the initial foreign-invested R&D in the 1990s turned out to be more "show" than substance and is today derisively referred to by both Chinese and foreign experts as "show R&D." Over time, both sides—foreign investors and Chinese officials—found this relationship unrewarding, leading to important changes in foreign R&D investments in China.[19]

The Role of State Sponsors and Leading Universities

China's state sector and universities also play distinct roles in attracting foreign high-tech investments, including R&D. As Adam Segal points out in his recent detailed study of Chinese high-technology enterprises (*minying*), the relationship between the state and these new domestic high-tech firms is often symbiotic.[20] Foreign investors who partner with these and other enterprises favored by, or close to, Chinese government officials can benefit substantially in terms of *guanxi* (connections). They also can gain better information on China's industrial, political, legal, and technological policies and strategies, which have in the past been difficult to discern due to a lack of transparency in Chinese policymaking. This type of competitive positioning also can be helpful in securing contracts with various Chinese ministries, each of which has independent procurement authority.[21] Therefore, carefully selected industry partners can serve as a

[19] This type of R&D might fit into Stoke's Matrix, in the empty quadrant that is the nexus of R&D neither for the sake of fundamental science nor for an applied purpose. See Donald E. Stokes, Pasteur's Quadrant: Basic Science and Technological Innovation (Washington, DC: Brookings Institution Press, 1997).

[20] Adam Segal, *Digital Dragon*, 18.

[21] In 1999, the State Development Planning Commission (SDPC) issued regulations intended to make China's government procurement system more centralized and somewhat more competitive. In March 2003, the

window on emerging opportunities as well as on policy and technology shifts in China. Foreign investors in some cases also select domestic partners that have government-financed R&D programs in order to leverage these assets for their own purpose.

The same strategy applies to leading universities, which foreign computer and telecom investors have partnered with due not only to many Chinese universities' fine IT or engineering and science departments, as well as for the purpose of recruiting staff and contracting out some discrete research projects (all of which occur), but also due to a university's close ties to particular Chinese government ministries. In the telecom sector, this appears to be a key reason behind at least some of the numerous technology transfer agreements and/or joint R&D programs that MNCs have signed with the Beijing University of Posts and Telecommunication (BUPT). The BUPT provides education and training in the telecom sector, ranks 31st among Chinese universities, and serves as a node on an important domestic Internet network—the China Education and Research Network (CERNET). More importantly, however, the BUPT falls under the Ministry of Education and thus (until recently) provided foreign investors with a window onto China's Central Committee leadership and other key ministry heads.[22] For many foreign partnerships with BUPT, R&D was, at best, a secondary objective.

Chinese universities also attract foreign R&D investment due to their long-standing reputation for high-quality education and/or for their location and connections within high-technology development zones. In particular, Beijing University and Tsinghua University, both located in the Chinese capital, are much sought-after partners. In the past, however, Chinese officials eager to attract higher levels of foreign R&D investment have at times openly suggested which university foreign investors should approach to set up an R&D center. In some cases, these were second- or third-tier universities or outside the preferred locations of Beijing and Shanghai.[23] Incidents such as this occurred mostly prior to China's WTO membership; since then, the practice appears to have

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SDPC was reorganized as the State Development and Reform Commission to oversee all government reform measures. David Snodgrass, 14.

[22] Interview with a foreign executive of a US telecom company in Beijing (July 2002). See, for instance, R&D partnerships set up by Nortel, Qualcomm, and Newbridge Networks cited in recent press releases: "QUALCOMM Forms Joint Research and Scholarship Programs with Beijing University of Posts and Telecommunications" (March 23, 1998); and "Newbridge Networks Signs Agreement with Beijing University of Post and Telecommunications" (May 9, 2000).

[23] Interview with US auto company representative in China (March 1998).

abated. Nevertheless, Chinese state ministries and universities remain key stakeholders in the foreign R&D investment trend and continue to seek, encourage, and facilitate these types of partnerships.

Technology Trials

While employed by both the computer and telecom sectors, technology trials as a form of Sino-foreign collaboration have been particularly prevalent in the telecom sector. In a technology trial, foreign high-tech firms invest in, provide the high-tech equipment for, and demonstrate the capability of advanced technologies that are new to China. Often, trials entail the installation of entire telecom networks in different parts of China, with foreign investors competing for whole city- or region-wide markets. Foreign-invested R&D frequently accompanies these technology trials, including R&D to localize foreign technology or to perform systems integration. As these trials initially coincided with the start of China's "Golden Projects" (digital telecommunications networks intended to be the foundation of a Chinese information superhighway), the competition, particularly in the mid- to late-1990s, was fierce among foreign telecom firms fighting for the right to install new networks dedicated to either the dominant European telecom standard—the Global System for Mobile Communications (GSM)—or the predominant US telecom standard developed by Qualcomm (the Code Division Multiple Access or CDMA standard).

From the foreign investor's point of view, the appeal behind participating in these technology trials (which continue today) is four-fold: to demonstrate a company's long-term commitment to the market; to demonstrate a technology's capability and its interoperability; to promote the company's own technological standard as the one that PRC officials should choose when they ultimately decide which technology and standards to adopt nation-wide; and to make a head start in gaining market share in China's telecom industry by capturing local, provincial, or regional markets (depending on the size and type of trial being conducted). In practice, however, technology trials appear (to the lay observer at least) to be a rather large gamble by foreign investors on the potential for future telecom investment opportunities in the China market. In the meantime, these trials constitute a technology windfall for regional Chinese authorities and communities. In fact, this strategy has not always proven successful, as foreign investors' experience in the mid-1990s with a new telecom investment model painfully demonstrated.

Finding a Way to Invest in China's Telecom Sector: The CCF Gamble

Due to the monopoly position of China's state-owned telecom company—China Telecom—foreign investors seeking a way to pry open China's market in the early-1990s found a willing partner in a newly emerging domestic rival, China Unicom.[24] Given the latter's distinct competitive disadvantage, China Unicom entered into a series of agreements and technology trials with several foreign telecom firms, utilizing a third-party joint venture as a vehicle for circumventing PRC regulations prohibiting foreign telecom operations and services. Known as "CCF" agreements (short for China-China-foreign), these complex, back-door partnerships were of questionable legality from the start but were tolerated by the central government for a time. Yet, as lawyer Stanley Lubman explains:

> A number of foreign companies were encouraged by high-ranking officials to use this device [the CCF model] . . . and to believe that it could give them a substitute for equity ownership. Use of this vehicle, however, was first criticized, and then declared illegal late in October 1998. In late 1999, foreigners who had used this device were warned that they had to negotiate the terms under which they would divest themselves of their interests in these joint ventures.[25]

By the central government's divestment deadline of September 1999, China Unicom's 40-plus CCF arrangements with dozens of foreign telecom investors had been terminated. Any CCF-related joint venture assets were expropriated, and foreign investors received only their original investment calculated at an "equitable" rate of return.[26] Yet, while the gamble might have earned foreign investors short-term benefits (i.e., increased access to industry leaders, *guanxi*, and an initial foothold in previously closed markets), the investment did not pay off for long and should serve as a cautionary tale for future foreign investors in China and other still-developing markets.

As this and other dynamics, trials, and tribulations described above demonstrate, the value-added chain of high-tech investments in China is a somewhat modified version of the more generic model outlined at the

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[24] China Telecom was an arm of the then-Ministry of Posts and Telecommunications (MPT).

[25] Stanley Lubman, "Through a Glass, Dimly: Perceptions of China in the American Business Community," Prepared for a conference on "Trends in China Watching," George Washington University (October 8–9, 1999).

[26] Ashley Heineman, "China and the Internet: The Equipment Supplier Perspective," briefing before China Telecom 2001 Conference (2001).

start of this chapter. With this in mind, the following section briefly outlines the evolution of high-tech R&D investments in China.

THE EVOLUTION OF FOREIGN HIGH-TECH R&D INVESTMENT IN CHINA

R&D investments by high-tech multinationals in China appear to have evolved in three distinct, though overlapping, stages:[27]

- *Exploratory and Strategic Partnerships* (early–mid 1990s)
- *Expansion of R&D* (mid–late 1990s)
- *Consolidation of R&D* (late–1990s to the present)

Although all of these stages are ongoing due to new entrants in the China market, each is defined by a different incentive driving foreign companies to invest in R&D in China.

Exploratory and Strategic Partnerships (Early–Mid 1990s)

The initial period of foreign R&D investment in China is best characterized as exploratory, strategic investment. In the early 1990s, a growing number of Sino-foreign joint ventures began to involve some form of R&D work. The primary purpose behind many of these early joint venture-based R&D programs was to form or enhance strategic partnerships needed to enter and prosper in the China market. Some also were part of a longer-term corporate strategy to gain a foothold in this critical market. Often, however, R&D investments were the product also of pressures put on foreign companies to accede to side agreements involving R&D as a condition for obtaining government approval needed to establish a Sino-foreign joint venture. Consequently, this was the era dominated by the aforementioned "show R&D" activity.

Given the motivation, it is not surprising that many of the nominal "R&D" programs established around this time were not what one would normally classify as advanced research and development work. Rather, many involved localization and other very basic development-related activities, if they conducted any form of R&D at all. Some of the centers

[27] The following analysis is mainly based on insights, anecdotes, and personal observations gleaned from a series of interviews conducted in Beijing, Shanghai, Hangzhou, Shenzhen, and Hong Kong in the summer and fall of 2002.

involved in actual R&D adapted technologies and know-how already in the public domain so as to avoid either intellectual property or export control concerns.[28] Most of these collaborations, however, involved little, if any, R&D, comprising instead simple donations of advanced equipment (such as computers) for training purposes, the establishment of R&D "labs" at universities (which appeared in some cases to be little more than rooms set up with foreign-donated equipment), or research funds for development work conducted by joint venture or university partners to assist in localizing foreign products. Since the main objective in many of these agreements was to appease Chinese officials and obtain approval for a joint venture—not to conduct R&D—it is unlikely that much advanced technology or know-how was transferred via these early agreements. In fact, concerns over intellectual property rights kept many foreign investors from considering more sophisticated collaboration.

The foreign investment climate pervasive during this period is summed up in a description of an agreement reached by the Canadian telecom firm, Nortel, in 1993. A case study of the company's investment strategy in China notes that, "For foreign multinationals like Nortel and AT&T, the writing was on the wall: local technology development and technology transfer to local partners would be pre-conditions for participating in China's telecom boom."[29] Before long, these technology transfer demands included foreign R&D investments.

Expansion of R&D Investments (Mid–Late 1990s)

During this period, the information technology market was booming in the United States, and China's own IT market was opening up further to foreign investment and growing increasingly competitive. At the same time, PRC officials were becoming concerned about the growing economic divide becoming apparent between the country's eastern and western provinces. Consequently, by the end of the decade, foreign investors were being encouraged to "Go West" to seek investment opportunities and had begun to take advantage of new incentive programs for investment in high-tech ventures outside of the more prosperous coastal provinces.

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[28] Interview with an American manager of an R&D center in Beijing (March 1998).

[29] Tony S. Frost, "Persistent Adaptability as Survival Strategy for MNCs in Emerging Markets: The Case of Nortel Networks in China," in Paul W. Beamish and A.E. Safarian eds., *North American Firms in East Asia* (Toronto: University of Toronto Press, 1999).

For a time, this initiative proved successful. In centrally located Xian, for example, IBM established a software development center, and Hewlett-Packard's investment plans included opening an "e-commerce technology research center."[30] According to a Chinese press account, "Since 1999, nearly 100 companies listed among the Fortune 500 have set up representative offices or research centers in major cities there [in China's interior]." In particular, foreign telecom firms welcomed this new open door to investment in China's inland provinces and the incentives and technology trials that accompanied the Western development campaign.

Other factors also drove the expansion of R&D centers in China during the mid- to late-1990s. The combination of an expanding global IT market, a vast increase in global venture capital resources, the growing inter-firm competition among foreign investors to set up some form of R&D center in China, and the expectation of China's near-term accession to the WTO all contributed to an optimistic view of China's future market potential and a rise in the number of foreign-invested (mostly joint venture) R&D centers in China during this period.

Also at this time, companies that had been in the market for a number of years began moving up the value-added production chain. They began to set up additional training centers and to collaborate with their joint venture R&D partners in localizing their products to fit Chinese technical standards and, in some cases, conducting systems integration work. In doing so, foreign investors often partnered with China's leading computer and telecom enterprises, such as Legend in the computer sector or Huawei in the telecommunications industry. Foreign investors also began to outsource to university-based researchers a limited amount of product development and design work. As with early R&D ventures, all of these activities were more "D" (meaning development) than "R" (referring to more sophisticated applied or basic research), although some university researchers were hired to do the latter type of research as well.[31]

In response to foreign interest in establishing R&D programs, leading Chinese universities began to develop a process for establishing and facilitating cooperative ventures and research contract agreements with foreign companies. No such process had existed during the earlier phase of foreign high-tech investment, but university researchers and

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[30] "Multinationals Eye High-Tech Sector in West China," *Renmin Ribao* (September 5, 2001).

[31] Interviews with university-based researchers in Shanghai and Guangzhou (March 1998).

administrators saw the value (and profit) in these arrangements and quickly moved to put a more formal process in place.[32] Multinationals also began to expand their strategic partnerships with universities around China, in part to recruit graduates as well as to broaden their reputation and product branding in the PRC.

By the end of the decade, however, the IT market had reversed course, venture capital was diminishing, and corporate budgets and expenses were being cut back. These dynamics, along with China's imminent accession to the WTO, ushered in a new phase of consolidated, more strategically motivated, foreign R&D investment in China.

Consolidation of R&D (Late 1990s to the Present Day)

With the PRC's long-awaited entry into the WTO now complete, many high-tech companies in the market for nearly a decade or longer are interested in moving up the value-added production chain and are seeking a local R&D base from which to do so. As a result, in contrast with the two earlier periods of R&D investment in China, the current phase is marked by a more considered, strategic approach to R&D investment. Driven by increasing economic pressures on high-tech industry and the growing global competition for international R&D, many foreign investors in China are now consolidating their overall number of research-related programs while simultaneously shifting toward more advanced R&D activities (the nature of these activities is discussed later in this chapter).

Due to recent WTO-related reforms, foreign high-tech enterprises are allowed in many cases to establish wholly foreign-owned subsidiaries in China, which are more attractive than joint ventures for conducting R&D. Moreover, many foreign investors have found their existing joint ventures difficult to manage—since nearly every decision must be negotiated with the venture's Chinese partner(s)—and are consolidating these ventures as well, often by forming a new wholly owned enterprise.[33] Consequently, corporate executives are more deliberately weighing the pros and cons of investing in different locations in China, choosing a strategic, central location(s) at which to base their consolidated R&D and commercial ventures.

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[32] Author interview with a group of Chinese university researchers in Shanghai who were among the first to be approached by foreign investors interested in hiring researchers under contract to conduct product-related R&D work (March 1998).

[33] Only R&D centers that are considered separate entities qualify for the tax credit and other important financial incentives offered to foreign investors.

Many foreign investors are opting to locate their newly consolidated operations in one of China's leading high-tech development zones. For some well-known high-tech corporations, the incentives offered by PRC authorities to locate in HTDZs (and the recently established science parks many zones have cordoned off) can include a period of free rent, favorable lease terms, and construction loan assistance. Many foreign investors, for instance, choose to locate in Beijing's high-tech Zhongguancun area or in the ShangDi Information Industry Base near Tsinghua University ("China's MIT") and close to several state-run research institutes. These locations offer foreign investors the space, advanced infrastructure, high-tech facilities, and urban amenities they require along with substantial financial incentives. Some have established mini campus-like settings in Beijing, Shanghai, and other urban areas around China, often mimicking on a smaller scale the look and feel of research centers found in Silicon Valley and similar high-tech corridors.

Due to the growing competition across China to attract the same top multinational high-tech firms, other companies are choosing to establish a base outside of the main city centers (primarily Beijing and Shanghai) to take advantage of incentive packages offered by local government officials in somewhat more remote, though still urban-industrial, locations. Nokia, for example, established in 2001 a new R&D center in Hangzhou, a city in the Pearl River Delta area surrounding Shanghai, and recently announced plans to consolidate its four existing joint ventures there.[34] For companies that locate in areas outside the capital, there is generally less competition with other foreign firms, closer relations with Chinese government officials, and lower employee turnover rates.

As foreign investors decide where to consolidate their ventures and R&D centers, executives now are giving more thought to the type of research work they plan to conduct at these centers. Today this activity appears more often to be what one would appropriately term R&D. Unlike earlier stages of nominal R&D investment, MNCs today view research and development activity in China as strategically (and not just politically) important to their long-term future growth—both in the China market and in the global context. Although still "more 'D' than 'R'," this activity is clearly more sophisticated than what came before and is intended now to produce real results.

[34] Ted Dean, "Nokia Under Fire," *Beijing Byte* (April 11, 2003).

CHARACTERISTICS OF PRESENT-DAY FOREIGN R&D IN CHINA

A number of important questions have not yet been addressed, such as how many foreign-invested R&D centers there are in China, what their common characteristics are, and whether these centers have produced any results. The following section combines trend analysis with snapshot observations of present-day foreign R&D investments in the PRC.

Estimates Vary on the Actual Number of Foreign-Funded, High-Tech R&D Centers in China

The absolute number of foreign R&D centers or facilities in the PRC is unclear, and there is no definitive estimate. Recent Chinese news articles put the number at anywhere between 120 and nearly 400 foreign-invested R&D centers spread throughout the PRC (though it is not known what methodology or criteria were used in calculating these totals).[35] Another recent study conducted by the Chung-Hua Institute for Economic Research on Taiwan estimates that there are 148 foreign high-tech R&D centers located in the PRC.[36]

Other accounts that break down the numbers by region are similarly difficult to assess. The Xinhua News Agency counts "at least 40" such centers in Shanghai in 2001, but reports in early 2003 that "more than 80 foreign-invested enterprises have established research institutions in Shanghai" (a remarkable rate of growth, if accurate).[37] Nor did interviews in Beijing, Shanghai, or other Chinese cities yield more definitive data. Industry and academic experts estimate the number of foreign R&D centers in Beijing and Shanghai at approximately 50 in each locale, while one source suggested there were 300 in Shanghai

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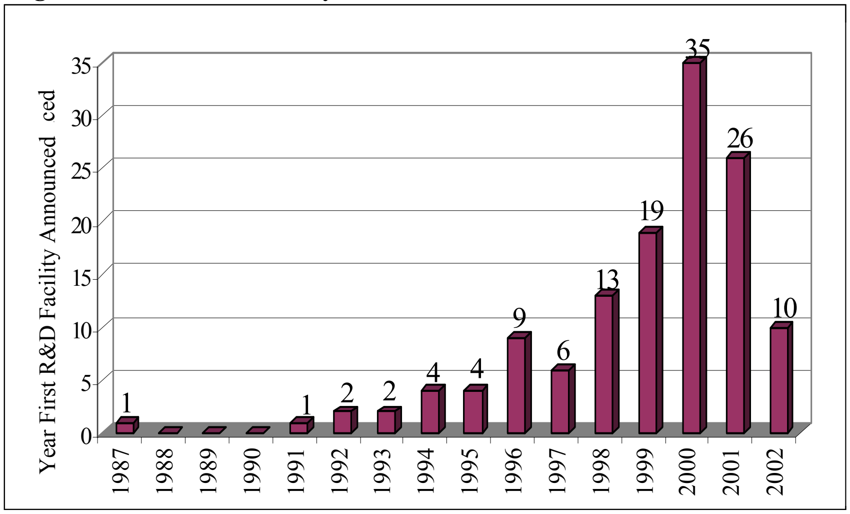
[35] Both the 120 and 400 figures are from estimates cited in articles found in the *People's Daily Online*. See "China Tipped to Become World Hi-tech Center" (June 2002), which notes, "Foreign businesses have set up over 120 R&D centers in China, and there will be 10 more this year," and "China's Foreign Trade Sets New High Despite Adverse Circumstances" (October 28, 2002), which cites, ". . . nearly 400 R&D centers of various types…" Charles McMillion cites reports from the year 2000 by China's Ministry of Foreign Trade and Economic Cooperation of "nearly 100" foreign R&D centers and a CAS figure of 124 such centers in 2001. See Charles McMillion, "China's Very Rapid Economic, Industrial, and Technological Emergence," in the US-China Security Review Commission, *Report to Congress of the US-China Security Review Commission: Documentary Annex* (Washington, DC: US Government Printing Office, July 2002).

[36] This figure is cited as part of a survey of 500 companies in China. See "Taiwan's R&D Should Differentiate From That of China," *Asia Pulse* (December 5, 2002).

[37] "More Multinationals Locate R&D Centers in Shanghai," *Xinhua News Agency* (December 13, 2001) translated in FBIS-CHI-2001-1213; and "Shanghai Announces R&D Center Construction Plan," *Xinhua News Agency* (February 9, 2003).

alone (presumably including small and medium-sized firm R&D activities). At the same time, the head of an R&D center in Beijing claimed there were only 50 "real" foreign-invested R&D centers in all of China.[38]

Figure 12: Number of Newly Announced ICT R&D Centers in China



Source: Stimson Center estimate (2003).

Looking only at foreign-invested R&D centers in the computer and telecommunications sectors—and over the entire period spanning 1990 to 2002—it appears that as many as 223 such "centers," "programs," or "labs" have been established for the purpose of R&D over this period, although some have since been consolidated and others are likely to have been terminated altogether.[39] The majority of these R&D centers began appearing in the late 1990s as the inter-firm competition surrounding R&D centers heated up, and Chinese investment policies offered additional incentives for companies investing in R&D. The numbers of

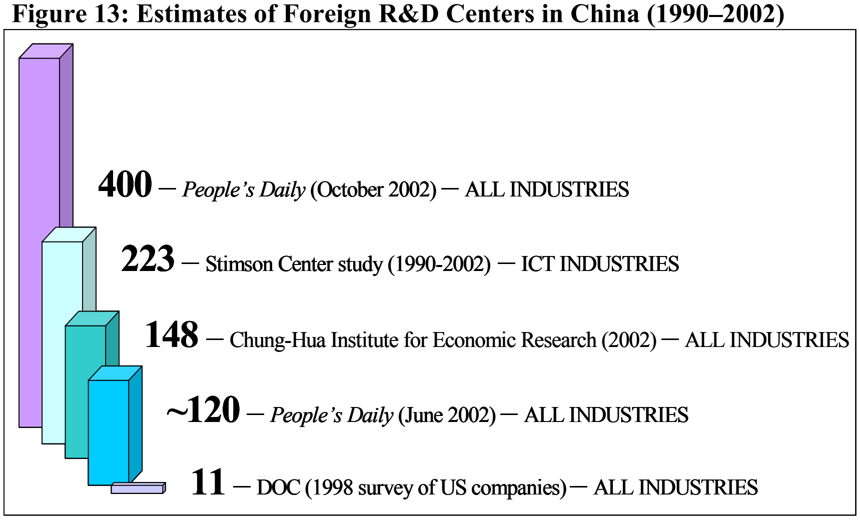
[38] Author interview (July 2002).

[39] This estimate does not count R&D-related licensing agreements, memoranda of understanding, donations of equipment, training centers, and other technology transfer agreements that often accompany overseas R&D. The criteria for inclusion on the list was that an R&D "center," "program," "lab," or university program appeared to be a stand-alone facility or separate entity devoted primarily (if not solely) to conducting R&D. Wherever possible, in compiling this list, Stimson staff tried to confirm the existence and basic data on each R&D program by telephone, fax, or email correspondence with each company. The list primarily includes leading high-tech multinationals and so misses an unknown number of small or medium-size enterprises that also might be conducting R&D in China.

new R&D centers, however, showed a decline after the year 2000, probably due in part to the downturn in ICT industry growth as well as consolidation of R&D centers by foreign investors (see Figure 12).

It is important to note that none of these estimates account for the termination of R&D centers, since notice of such an event is rarely, if ever, announced publicly. In the absence of any comprehensive government or industry-collected data, particularly for developing countries, the only available means today of quantifying overseas R&D activities rests on a review of corporate press releases, filings to the Security Exchange Commission, corporate websites, and similar public sources. As a result, all of the estimates are probably somewhat inflated. Also, each might inadvertently count as R&D centers the numerous collaborative efforts that represent some form of technology transfer but may not appropriately fit the definition of R&D (e.g., licensing agreements, donations of high-tech equipment, training centers, and so forth).

Figure 13: Estimates of Foreign R&D Centers in China (1990–2002)



The end result is that there is no clear estimate of foreign-invested, high-tech R&D centers in China today. Nor is it apparent where all of these centers are located, although anecdotal evidence suggests that the majority can be found today in either Beijing or Shanghai. It is also difficult to judge the actual rate of growth in the number of R&D centers given such widely varying estimates. Although the studies cited above are all fairly recent, it is unclear whether the wide disparity in estimates represents the actual rate of growth in R&D centers or merely a realization of R&D investment as a new trend and several early attempts to quantify it. The latter is more likely to be the case.

Over the past year or so, Chinese government officials and industry experts have become interested in tracking this trend and are attempting to compile data, raising the possibility that these statistics will appear one day in China's national *Statistical Yearbook*. What can be said with certainty today is that this trend has grown quickly, particularly over the past few years, and that it represents an important new dynamic in the China market.

Yet, as the evolutionary path of high-tech R&D in China shows, the rise or fall in absolute numbers of foreign R&D centers is not as important as the motivations that underlie their existence. Whether or not these centers will, in a significant way, contribute to China's development, affect US economic and security interests, or impact bilateral and international trade depends not on their overall number but on their intended purpose and their success in achieving these aims. For instance, as foreign high-tech R&D in China became a more serious undertaking toward the end of the 1990s, the number of joint venture-based R&D centers probably declined as companies began to consolidate their research and commercial ventures under one roof. A mere count of R&D centers also would miss the important shift that occurred from "show R&D" activities to the more substantial research work taking place today. Accordingly, future analyses on R&D in China will have to take into account the history of these activities in determining the significance of any statistical data that might emerge.

Foreign R&D Investors Represent Many Different Nations

Utilizing the estimate of approximately 200 foreign ICT-related R&D centers in China (established over the period of 1990–2002), two observations stand out. First, US multinationals established more than half of these (128). This is not surprising given the leading role of US companies in high-tech industries such as computers and telecommunications. Second, many other countries (at least 14 others) also have formed ICT-related R&D centers in the PRC over this time period. Of the 82 different companies invested in the more than 200 R&D centers, 41 were from the United States, 12 were Japanese, six were Hong Kong companies, four were Canadian, three were Swedish, another three were from Taiwan, two were from South Korea, and there were two each from France, Germany, and India. Also, Finland, the

Netherlands, Singapore, Belgium, and South Africa each invested in one ICT-related R&D center over this period of time. As noted above, it is unclear exactly what type of R&D these centers are engaged in or whether all of them still exist. Nevertheless, the diversity of nations involved in this type of technological activity in China further demonstrates the globalization of high-tech R&D and its growing influence in the PRC.

Evaluating the Operations and Success of High-Tech R&D Centers in China

There are two important factors to consider in gauging the potential impact these centers might have on China's economy and on US business interests: inputs and outputs. The first involve issues of funding, management, and operations while the other assesses results.[40]

Funding

Foreign multinationals have been pouring enormous sums of money into R&D programs and other investments in China, particularly over the last few years. Motorola and Microsoft top the list, with billions of dollars either donated or invested in the China market overall. Motorola alone has invested in 18 different China R&D centers. In part, these are investments in China's future market, which help to demonstrate the company's commitment to China for the long-term. More and more, however, these centers are established mainly for the purpose of conducting genuine R&D.

Much of the initial funding for R&D goes to construction and other start-up costs, although some of these expenses are reduced or refunded under preferential investment policies. In particular, MNCs are sought-after as "anchors" for China's burgeoning new "science parks" and other similar high-tech zones. Also, R&D centers that include testing or other types of labs may require additional equipment and infrastructure and thus might incur higher initial costs.

Management

While some R&D centers continue to be housed in modern office buildings in downtown Beijing and other major east-coast cities, MNCs

[40] The observations presented in the following section are based on the author's interviews with more than a dozen R&D managers in China during 2002, the majority of whom represented US multinationals.

also have begun to construct new and/or consolidated R&D centers elsewhere in China, some seeking to model their China R&D lab on those found back home. A few are attempting to create a campus-like atmosphere by way of similar building architecture (but often on a much smaller scale) and an office layout typical in Western high-tech firms. In each case, emphasis is placed on creating an innovative environment. This frequently translates into modern office facilities that allow room for extracurricular activities in addition to the de rigueur rows of cubicles.

Similarly, the management techniques employed at a number of these centers mirror those of the parent company. To inspire innovation, foreign R&D centers often allow casual office attire and informal relations between management and staff. (If the Chinese employees had pets, they would surely be welcome to bring them to the office.) In other words, the intangible factors that fed the IT industry boom in Silicon Valley are being replicated, at least to some degree, in Beijing, Shanghai, and elsewhere in China.

Given the general lack of management expertise among Chinese nationals, however, the majority of upper management staff remain either expatriates or Chinese returned from abroad (many of whom have experience working with high-tech firms in the United States and elsewhere). Training local staff is a high priority for nearly every R&D center due to concerns over increasing costs, production quality, and the still under-appreciated importance in China of sales, marketing, and customer service.

As the costs of basing foreign expatriates in China have grown, so has the incentive for foreign investors to develop indigenous capabilities. According to interviews with foreign R&D managers, most local Chinese staff have proven quite capable in completing discrete research tasks. Many local hires are recruited from China's leading universities, and the majority have graduate degrees. The primary concern managers have at this stage (in addition to high employee turnover rates) is how to develop among their Chinese staff a more innovative mindset. There are a substantial number of internal training programs available to local employees that are sponsored by foreign investors in an effort to transfer the understanding they hope will lead to more "out of the box" thinking and innovation. A brochure for Nokia China R&D, for instance, cites "over 1,000 in-house courses available." E-learning programs also are beginning to take off. But, at present, the requisite management skills needed to see a high-tech project through from concept to design and production are generally lacking in China, as is individual initiative on the part of many otherwise well-trained, intelligent, and highly skilled local employees.

Although it appears that most R&D managers are expending quite a lot of effort to transplant proven management and innovative styles to the Mainland, this strategy may or may not succeed in China over the long run. Some foreign managers show clear frustration over the slow progress achieved to date in transplanting high-tech innovative skills and ideas. But, as pointed out by one R&D manager with long-time experience in the China market, what has worked in Silicon Valley and elsewhere might not translate exactly in the Chinese context. By this he meant that the way Chinese researchers at these centers will become more innovative is likely to take somewhat different form. For example, he found largely by accident that his staff produced better and more innovative results when working in small teams rather than as individuals. As this example and the continued need for training suggests, there likely will be a period of trial and error before many of these centers become highly productive or self-sustaining.

At present, however, most R&D managers seem intent on changing Chinese work habits and mindsets to more closely conform to Western business models and style of innovation. Chinese officials and employees are eager to absorb these methods and to adapt their behavior accordingly. Yet Chinese researchers are likely to develop their own innovative style. To be successful, foreign managers will have to identify and adapt this to their advantage.

Many R&D centers also remain plagued by high turnover rates (much like other MNC enterprises in China), particularly those located in large cities where job opportunities are far greater. Some of those who leave are headed for the United States to obtain graduate degrees (and might work for the company's headquarters or other high-tech enterprise while studying abroad); others simply find a higher-paying job elsewhere, and a growing, though still small, number are leaving to work for or establish high-tech start-up enterprises. Although the pay at a Chinese start-up is generally less than at a foreign-owned MNC—and the risks extremely high for those who take this independent path—a growing number are finding that they can do similar work and do so in a more comfortable, non-foreign environment. Moreover, some find that they are better able to employ the high-tech skills they have gained through working for MNCs (in China or abroad), where their work typically involved only part of a larger research project. By working at a

Chinese start-up, they have a greater chance and more need to stretch their talents and know-how.

For the majority of local hires who continue to work at multinational R&D centers, the cost to foreign investors is rising. One US computer company, for example, estimates the cost of hiring a local software engineer as higher now in China than in India and expects this to rise (with costs indexed for eastern China only). Although still well below similar costs in the United States (there remains an approximate 4:1 US-China wage gap in this high-tech sector), the margin is beginning to narrow and presents a growing concern for some R&D managers in China. Furthermore, while most R&D centers at present have a staff of about 100 persons, most have agreed (informally or by contract) to hire and train a set number of local employees over a period of years. One recently opened center expects to expand its staff tenfold within the next five years. Others have more modest projections, but all expect (and are expected by Chinese government officials) to grow in size. Unless these centers become highly productive and profitable, the added burden of tens or even hundreds of new employees will only exacerbate difficulties in training and maintaining qualified local staff.

Finally, some R&D centers employ or fund visiting scientists, fellows, and interns from abroad as well as from Chinese universities. Unlike years past, much of the work they do now is conducted at the R&D center facilities rather than at a university or other off-site location. These programs provide a way of supplementing the R&D center's work in areas of basic or applied research while reducing overall research costs; outsourcing is now only done in areas of research that are outside the center's core competency, since it is more expensive (and risky in terms of IPR protections) than conducting in-house research. Having fellows and others do research work on the premises ensures that any results remain formally the intellectual property of the center. It is also a way to recruit more experienced staff and to build connections throughout the Chinese high-tech and scientific communities. Given the still-large hole left by the "lost generation" from China's Cultural Revolution, many foreign investors also view these types of programs as investing in China's future leaders.

Modes of Operation

There appear to be three general models governing how foreign R&D centers operate and relate to their parent companies, which correspond to how R&D centers operate in other parts of the world.[41] Although each center is closely linked to its parent company, there are differences in the type of work they do and in the type of results each is expected to produce.

A majority of the foreign R&D centers today appear to be satellite organizations within the overall hierarchy of the multinational corporation. Thus, these remote centers generally operate following a bottom-up approach to R&D. That is, the centers located in China (and elsewhere) are intended to help identify for their parent company new ideas and product innovations based on the eccentricities of the market in which they reside. Typically, these types of R&D centers do not work on global project teams but act more as "listening posts" and are innovative primarily in terms of adapting existing product lines to better fit local market conditions. Although these types of centers are important assets in a global economy, they are likely to be drawn down or sacrificed in a time of tight budget constraints, at least for a period of time. A smaller number of centers that operate under this model are more directly and intimately involved in the company's overall R&D activities and pride themselves on bringing innovative ideas from the local market to the global conglomerate.

The second model reflects more of a top-down approach. In these centers, the local R&D staff is tasked with a project (or a discrete piece of a research project) by the parent company based on the skill level, location, and other center- or market-specific characteristics and advantages. Researchers at these types of centers are more likely to be working with colleagues from the company's corporate headquarters or with other R&D centers around the world, frequently doing so in real time.

Finally, a very small number of centers claim to be fully integrated with their parent company and affiliates, describing the China-based R&D center as an equal participant in all corporate decisions, R&D work, and other global corporate activities. As described by an executive of one such center, in this model there are no barriers between the R&D work conducted at the company's headquarters and the work done at the lab in China (or the company's other global R&D centers). As in the other examples, however, it is impossible for an outside observer to discern exactly how each center operates in practice.

[41] This section draws on observations and insights from interviews with nearly a dozen foreign R&D managers of high-tech R&D centers as well as interviews with executives from two Chinese start-up enterprises conducted in the summer and fall of 2002.

Products, Patents, and Profits

It is also extremely difficult to gauge how successful or profitable these centers are, for several reasons. First, it is simply too soon to determine how well many foreign R&D centers in China are faring since most have only recently been established, and corporate executives are understandably cautious about discussing publicly any problems the center might be having. Second, unlike manufacturing ventures, R&D centers may or may not produce anything tangible or quantifiable. In most cases, in fact, the results achieved through research—particularly in the computer software industry—are simply forwarded (or emailed) to the company headquarters or to a manufacturing plant somewhere else to be integrated into the global product line. The contribution, for instance, made by the Microsoft Research Lab in Beijing to Microsoft's new Tablet PC technology was apparent to the public mainly through press releases and interviews conducted by the lab's deservedly proud director.[42]

In addition, while some products are emerging from these centers, it is not clear whether they are entirely new innovations or, more likely, existing products newly adapted to better fit local market conditions (activity sometimes referred to as "glocalization").[43] The IBM Research Lab, for instance, boasts the "Chinese Workpad," a new-generation personal digital assistant (PDA) device that is loaded with Chinese-language software. Not surprisingly, for the two industries studied, many of the products advertised by R&D centers in China are software upgrades or systems integration solutions. Also, given the size of China's wireless market (currently number one in the world), many of the results are geared toward wireless applications, whether for mobile phones, PDAs, or E-commerce programs (which, in China, is conducted mainly by mobile phone using cash on delivery for payment).

This leaves profits and revenue as perhaps the best near-term measures of effectiveness. But these figures are generally considered propriety information and are not easily accessible. Surveys conducted by the firm A.T. Kearney, however, consistently show that the majority of foreign investors in China (59 percent in 1998) have yet to break even

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[42] The Microsoft Research Lab in Beijing contributed the "digital ink" handwriting tool used in the new Tablet PC. Pete Engardio, Aaron Bernstein, and Manjeet Kripalani, "The New Global Job Shift," *Business Week* (February 3, 2002), 50.

[43] In informal interviews with foreign R&D managers in China in the summer and fall of 2002, very few cited new products or technologies developed at their center when asked about research results.

or make a profit.[44] Foreign-invested R&D centers are likely to be in a similar situation.

As for patents, some R&D centers have applied for patents in the PRC, although most appear to file in their home countries as well, and some do so exclusively. Any new technologies stemming from wholly foreign-owned R&D centers in China—which is now the preferred type of venture for foreign high-tech investments—are considered to be the intellectual property of the parent company. These patents, therefore, are filed initially (and in some cases exclusively) in the MNCs' home country. As such, it is difficult to distinguish patents resulting from R&D centers in China from other corporate R&D efforts around the world.

Thus, at this stage, it is not clear whether foreign-invested R&D centers in China are producing their intended results. There are few indicators of progress available and collection of much more detailed data is needed to make an accurate assessment. At present, financial and other inputs into foreign-owned R&D centers seem high compared to observable, innovative output. This, plus the fact that management training remains a clear priority and area of concern for foreign R&D managers, suggests foreign investors are encountering some difficulties in conducting innovative research in China or that producing truly innovative results will take some time. Yet, many of these centers have only recently been established, and more time and data are needed to determine whether they will succeed in the long run.

THE FUTURE FOR R&D INVESTMENTS IN CHINA

As this chapter has outlined, the emergence of high-tech R&D activities in China shares many characteristics with the growing number of R&D centers appearing in other far corners of the world. As multinationals seek greater access to new markets and innovative ideas around the world, the overall number of overseas R&D centers is likely to increase in China and elsewhere.

Today, the trend toward global R&D is well recognized by the local and foreign business communities in China, which was not the case only a few short years ago. As a result, analysts and policymakers are likely to have a much better understanding of this rapidly developing trend as well as more definitive estimates, indicators, and statistics on this activity

[44] Thomas Klotz, "Global Companies and Investment in China," briefing before the OECD/China Conference (September 12, 2000).

in the years to come. In the meantime, the following chapter attempts to weigh the pros and cons of foreign high-tech R&D in China based on what is known today of this evolving trend. It also assesses the possible implications for China's development, US-China relations, and US national security and economic interests.

— 5 —

Conclusions: Risks, Rewards, and Implications of High-Tech R&D in China

"Enter the Dragon"[1]

The advent of foreign-invested, high-tech R&D in the PRC during the 1990s has ushered in a new phase of China's Open Door to the world. But what impact is it having, or will it have, on China's economy? What rewards and what risks does international R&D activity entail, particularly in terms of China's own drive to modernize? Similarly, what does this trend imply for efforts to maintain US competitiveness in critical high-tech industries? And what effect will the trend toward more global R&D have on future US-China relations? While it is still too early to know the full impact foreign high-tech R&D in China will have, this trend is sure to affect both US and Chinese economic, political, and security interests. Already, the PRC's emerging role as a high-tech innovative hub is beginning to impact the United States, the region, and the world.

THE IMPACT OF GLOBALIZATION AND FOREIGN-INVESTED HIGH-TECH R&D ON THE PRC

The present wave of globalization that began in the mid-1980s has coincided with the PRC's own efforts since 1985 to reform and restructure the nation's economy and S&T system. Nearly two decades later, China is, by all accounts, beginning to emerge as a serious high-tech competitor in its own market and in a few key sectors, including computer hardware, software, and telecommunications equipment. Despite persistent developmental challenges, it might not be long before the PRC becomes a global high-tech competitor as well.

The large amounts of foreign direct investment entering China and the introduction in the 1990s of R&D from abroad have clearly benefited China's modernization efforts. At the same time, these inputs increase the PRC's dependence on foreign technology and know-how, posing an

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[1] Title of a recent study on China's computer industry by the Institute of Electrical and Electronics Engineering (2002).

ongoing dilemma for Chinese policymakers. Following is a discussion of the benefits derived from these trends as well as the potential risks to China's economic and security interests.

Reaping the Rewards of Globalization and Foreign High-Tech R&D Investments in China

There are numerous ways in which the PRC benefits from foreign-origin R&D investment. In addition to direct technology transfers through Sino-foreign contract or venture agreements, high-tech R&D investments from abroad are having substantial spillover effects on the Chinese economy and, possibly, on China's defense sector.

Spillover and Indirect Effects of Foreign-Invested High-Tech R&D in China

From a strategic perspective, foreign-invested R&D plays an increasingly critical role in the PRC's long-term S&T development goals. A main objective of China's scientific modernization and long-term technology development plans (as outlined in Chapter Three) is to acquire from foreign investors the modern innovative concepts and technology development skills needed to bridge China's own "Valley of Death"—the wide gap that exists in the United States and elsewhere between the realization of new advances in basic research and the market forces that can help to bring these ideas to fruition. Foreign-funded R&D centers in China, which focus mainly on the key areas of applied research and technology development, are helping to fill this critical knowledge gap.

Furthermore, the emergence of foreign-invested R&D could prove particularly valuable to China in that, unlike most developing countries, the PRC enjoys the advantage of a sound and highly skilled scientific base. This technical foundation is sure to aid, and possibly accelerate, China's efforts to advance its technological modernization, particularly as the PRC becomes better able to integrate existing skills with the applied research and technology development capabilities gained through partnerships and collaborations with industry researchers from abroad. As outlined in Chapter Three, PRC leaders already have put in place many of the policy, institutional, and legal foundations China needs to better exploit technology and know-how from abroad.

Foreign R&D investments also are aiding China's efforts to expand, enhance, and disseminate scientific knowledge throughout the country. PRC officials and society place a high premium on education, and Chinese students already excel in mathematics and the basic sciences.

National education and training efforts have accelerated over the past several years following the central government's 1995 "Decision on Accelerating Scientific and Technological Progress," under the program to increase the overall "Informatization" of China's economy and society, as former state workers seek (or are pushed) to develop new, marketable job skills and PRC researchers, scientists, and as engineers are encouraged to "jump into the sea" (i.e., enter the market or private sector). Today, the emergence of foreign high-tech industry and R&D centers in China allows many more Chinese to improve their skills (and their paychecks) without having to travel abroad. More importantly, Chinese employees working for foreign R&D centers in China have access to modern research and development practices and processes, including innovative management techniques and other aspects of high-tech industry development that previously were accessible only to students and workers able to interact with high-tech companies overseas.

China's civilian S&T community, too, is reaping the benefits of globalization and foreign-invested R&D, allowing them to more fully participate in world scientific conferences, large-scale research projects, and other professional activities. This is in part due to IT advances that have broadened access in China and elsewhere to international scientific and technological know-how (as discussed in Chapter Two) and to the growing numbers of exchanges taking place both in China and abroad between PRC and foreign scientists. R&D centers play a role in fostering these interactions by sending Chinese employees to visit corporate offices abroad for training, by sponsoring interns and research fellows, and by hosting visiting foreign scientists, engineers, technicians, and others at their centers in China.

Another strategically important benefit accruing from foreign R&D investments in China is continued improvements to the Mainland's technological infrastructure. These advances are due to a mix of domestic and foreign inputs. First, to attract foreign high-tech investors, Chinese officials are expending large sums of money to improve municipal IT and other technological infrastructure, particularly in areas within and surrounding high-tech development zones.[2] In turn, foreign investors drawn to these areas contribute to developing China's technological base in a variety of ways. For example, foreign telecom

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[2] The World Bank and other international sources of funding, such as Japan's Export-Import Bank, supplement PRC expenditures on high-tech infrastructure. See William Boulton and Phyllis Genther Yoshida, *Information Technologies in the Development Strategies of Asia* (Washington, DC: International Technology Research Institute, 1999), 48.

firms have provided substantial financing, telecom equipment, and know-how as part of Sino-foreign technology trials (discussed in Chapter Four). Consequently, millions of miles of fiber optic cable have been laid and new-generation telecommunications networks installed across the PRC. The role of telecom R&D labs, in part, is to integrate, adapt, and test these and other foreign telecommunications equipment and network connections to ensure their compatibility with local technology and market conditions. Some MNCs also provide access to their China R&D test labs as a service to local Chinese telecom firms and startup enterprises.[3] Advanced technological inputs and opportunities such as these undoubtedly are aiding Chinese enterprises to accelerate their own development and their capacity to expand domestic high-tech infrastructure. For example, China is producing indigenously developed fiber optic cables as well as domestically produced telecommunications switches and routers, which are now competing with foreign-made brands in China. In fact, the Chinese firm, Huawei, commands the greatest market share in the PRC for optical systems equipment, out-selling foreign competitors such as Nortel and Lucent.[4]

Lastly, in addition to impacting China's civilian scientists and industry, there is the *potential* spillover effect from foreign high-tech R&D in China on PRC defense capabilities.[5] Due to outside analysts' limited understanding of how China's defense industry and military function and interact—with one another or with the civilian sector—one can only speculate as to whether R&D and other technologically advanced foreign inputs have benefited or will aid China's defense modernization efforts.[6] But given the very murky line between civil- and defense-related industry in China, there is bound to be some spillover

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[3] Interviews with foreign managers of, and visits to, R&D centers in China (2002).

[4] "Striking When The Time Is Ripe," *Fiber Optic News*, vol. 22, no. 23 (June 10, 2002).

[5] There is also the risk of illicit gains through espionage or violations of US export control laws, as demonstrated in recent years in the case of commercial satellite-related transactions, which were the focus of the 1998 Cox Commission and subsequent legal action by the US Justice Department. Piracy, too, is a serious concern in China, particularly in computer software. See Business Software Alliance, *Eight Annual BSA Global Software Piracy Study: Trends in Software Piracy, 1994-2000* (June 2003), available online at http://www.bsa.org/globalstudy/2003_GSPS.pdf.

[6] While China's defense conversion efforts have been largely successful in terms of spin-off production of commercial goods, it is not clear whether China's defense industry has had any substantial success in converting commercial technologies to military use. For a useful overview of China's defense industry in the era of globalization, see John Frankenstein, "Globalization of Defense Industries: China" (Washington, DC: The Atlantic Council, February 2003).

from foreign technology investments in R&D that are of interest to the Chinese military.

Although continuing Tiananmen-era sanctions and export control regulations prohibit many types of direct defense-related sales or collaboration with PRC entities, foreign R&D activities in China could conceivably be of indirect assistance to China's military modernization campaign. For example, local Chinese employees working at foreign R&D centers may gain an in-depth understanding of how foreign technologies are developed and function. In some instances, R&D activity has included integrating foreign technology with local systems or making foreign technology compatible with Chinese technical standards. This latter form of knowledge transfer (systems and standards integration capabilities), in particular, could be of potential use to China's defense modernization goals, especially in developing asymmetric capabilities. For this and other reasons (discussed in a separate section below), extensive knowledge transfers through R&D in China could pose risks for long-term US security as well as economic interests.

PRC policymakers also recognize the potential for advances in civilian S&T and commercial know-how to contribute to Chinese defense industrial capabilities. For example, Chinese officials announced in May 2000 a new policy of sending military officers to attend civilian universities—including the country's premier institutions—for technological education and training. At the same time, this policy initiative is likely an indication of the difficulties the PRC continues to face in modernizing its defense sector, which substantially lags behind advances in the civilian economy.[7] But, at the over 50 institutions of higher learning taking part in the training program, military officers might have the opportunity to interact with foreign high-tech firms and university-based R&D centers. In this and other ways, China's military and defense industry sector might benefit indirectly from foreign high-tech R&D investments. But mere access to foreign technology and ideas does not necessarily translate into new capabilities, as China has learned through decades of largely unsuccessful attempts to effectively exploit technology transfers from abroad.

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[7] Per a joint State Council and Central Military Commission "Decision on Establishing a System for Training Military Cadres by Reliance on Regular Institutions of Higher learning," dozens of civilian Chinese universities have agreed "…to meet the requirement of building a strong military through science and technology…". This Decision is cited in Information Office of the State Council, *China's National Defense in 2002*, Part V (December 9, 2002), available online at http://www.china.org.cn/e-white/20021209/. The White Paper also notes a State Council directive to establish an experimental degree program in military science.

Direct Benefits to Chinese Enterprises from Foreign R&D Investments

In addition to the broader spillover effects on Chinese society, foreign-invested R&D in China also provides direct benefits at the enterprise level. Evidence of China's commercial high-tech transformation, aided in part by foreign R&D investments, is demonstrated in the advances PRC enterprises have made in expanding domestic market share, developing more modern product lines, and implementing increasingly innovative and internationally focused business strategies.

Chinese high-tech enterprises today model themselves after Western—and particularly US—companies and are becoming increasingly competitive in the local market. For example, the company claiming the largest market share in the manufacture of personal computers (PCs) in China and for all of Asia is Legend Computer Systems—a spin-off from the Chinese Academy of Sciences founded in the mid-1980s. Legend also holds the number two spot in China after Hewlett-Packard in sales of laser printers. In addition to manufacturing and designing its own brand-name PCs and laptops (including key components such as the electronic motherboard), Legend produces some of these on a built-to-order basis, boasts thousands of distribution nodes throughout the country, has established its own domestic R&D lab and recently opened an R&D center in California's Silicon Valley (as a "listening post"), is publicly traded, and has begun to export its products abroad.[8] As these activities make clear, Chinese companies (with backing from the state) have the capacity to rapidly develop into commercial competitors and can compete across the entire business spectrum.

While Legend is the forerunner (and still remains more the exception than the rule), other Chinese high-tech enterprises are starting to give foreign companies a run for their money by competing for market share in a number of high-tech sectors. In computer hardware, the US Department of Commerce notes ". . . domestic manufacturers have captured more than 70 percent of Chinese PC sales while US suppliers have held much of the remainder."[9] In computer software, Chinese

[8] Legend's share of the Chinese PC market is over 30 percent, and the company is traded on the Hong Kong Stock Exchange. See Allan R. Gold, Glenn Leibowitz, and Anthony Perkins, "A Computer Legend in the Making," *The McKinsey Quarterly* (June 22, 2001), 73.

[9] US Department of Commerce, *ExportIT China: Telecommunications and Information Technology Market Opportunities for Small and Medium-Sized Enterprises* (Washington, DC: International Trade Administration, Office of Trade Development, Information Technology Industries, April 2003).

companies such as Founder, Red Flag, UFSoft, Neusoft, Kingdee, and Top Group, among others, are both partnering and competing with foreign high-tech leaders such as Microsoft, Oracle, IBM, and Sun Microsystems. In telecommunications, Chinese firms Huawei Technologies, Zhongxing Telecom, and Datang Telecom are but three government-backed, high-tech competitors who are quickly gaining ground against foreign equipment manufactures, including Ericsson, Lucent, Nortel, and Cisco Systems. Although Motorola and Nokia still dominate China's handset manufactures, domestic enterprises such as Bird, TCL, and Konka are chipping away the leaders' market share.[10] Moreover, in the semiconductor sector, US government analysts judge China now to be only two years or less behind US manufacturing technology and only one generation behind the commercial state of the art.[11] These and other Chinese companies—through a combination of strategic alliances with foreign high-tech companies (including on R&D), talented and comparatively low-cost labor, low-priced national brands, broad government support, and, increasingly, their own high-tech R&D efforts—are beginning to alter the image of the "made in China" label.

Many of China's high-tech enterprises enjoy R&D relationships with foreign MNCs. As these enterprises' growing competitiveness suggests, China is reaping the benefits of these interactions, which have helped industry become China's leading contributor to R&D funding. This progress, however, has been possible only in combination with nearly twenty years of state-funded S&T promotion through technology commercialization programs and PRC policies emphasizing new indigenous technologies and standards. The Chinese telecom firm, Datang, is a good example of this long path to becoming a modern high-tech Chinese enterprise. According to the company's promotional materials, "Since the Eighth-five Years Plan [sic], Datang Group has undertaken more than 60 key projects from [the] National Planning & Development Committee, Ministry of S&T, Key Promotion National Program, Torch Program, and the '863' National Projects, as well as 330 key R&D projects from Ministry of Information Industry and the former ministry of Telecom & Posts." As this litany of state-funded programs reflects, foreign-invested R&D is a contributing factor to China's recent

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[10] Bruce Einhorn, "High Tech in China: Is It a Threat to Silicon Valley," *Business Week* (October 28, 2002).

[11] General Accounting Office, *Export Controls: Rapid Advances in China's Semiconductor Industry Underscore Need for Fundamental US Policy Review*, GAO-02-620 (Washington, DC: US Government Printing Office, April 2002).

high-tech advances, but by no means the only one. Yet, as discussed in detail later in this chapter, foreign R&D collaboration has been a critical factor in aiding Datang's efforts to develop a new-generation technology standard that is very likely to have long-term national, and possibly global, repercussions.

Today, more than 20 years after the announcement of China's Open Door and a decade and a half of market- and technology-oriented structural and policy reforms, the PRC has become the world's sixth largest economy, the third largest manufacturer of IT products, and ranks fourth in the global share of computer production.[12] In the year 2000, three Chinese telecom firms made *Business Week* magazine's list of the global top 200 IT enterprises (China Mobile, China Unicom, and Hong Kong Legend Group) and two recently made the magazine's 2002 list of the top 100 IT companies (China Unicom and UTStarcom, due mainly to rapid revenue growth).[13] The fact that these and other high-tech Chinese enterprises are the topic of numerous articles, case studies, and book-length analyses and are fast becoming recognizable names not only in China but also around the high-tech world, testifies to the growing prominence of China's budding high-tech industry.

To expand on their success, China's high-tech entrepreneurs are starting to look overseas to market their homegrown products to the international marketplace. In doing so, they are looking not only to Asia and the developing world, but also to the US and European markets. Others are joining Legend in promoting sales or exports abroad, including Huawei and Zhongxing Telecom. These and a growing number of Chinese companies such as Huge Dragon and China's largest manufacturer of high-definition televisions, Konka, are also following Legend's lead in opening up R&D centers both at home and abroad. The latter are located primarily in the area of Silicon Valley and generally serve as "listening posts" (a typical first step in entering new high-tech markets) to alert Chinese companies to new market trends, innovations, and, in some cases, clients.

All of these efforts are being helped along by the large overseas Chinese population, which is increasingly tied together via informal

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[12] Kenneth Kraemer and Jason Dedrick, "Enter the Dragon: China's Computer Industry," *IEEE Computer*, vol. 35, no. 2 (2002), 28–36.

[13] The companies' rankings in each survey were as follows China Mobile (6th), China Unicom (80th), and Hong Kong Legend Group (128th) on the 2001 list; on the 2002 list, China Unicom ranked 80th, and UTStarcom claimed 90th place. See "Three Chinese IT Enterprises Rank Among World Top 200," *People's Daily* (June 20, 2002); and "The Information Technology 100," *Business Week* (June 24, 2002), 92–120.

communications networks such as university alumni groups, industry associations, and dedicated Internet websites. Interviews and anecdotal information suggest that these informal ties are beginning to yield modest business opportunities for some Chinese high-tech and start-up enterprises, including contracts with US-based high-tech firms for product design work to be completed by Chinese researchers on the Mainland.[14]

Yet, the impressive gains and achievements of China's growing number of high-tech enterprises do not mean that the PRC is about to surpass or even match US commercial high-tech capabilities anytime soon. It might take many years, a decade, or even longer (if ever), and US industry will not have been standing still in the meantime. Many of the advances apparent in China's high-tech manufactures and exports still depend in large part on foreign technology, know-how, and high-tech components.[15] Moreover, US companies still dominate China's computer software market and other high-tech sectors such as mobile handsets. More importantly, US industry maintains a wide lead in terms of innovative capacity, and there is an even wider gap in defense technology capabilities.

In fact, there are two key areas where the PRC still lags significantly behind in S&T capabilities relative to most industrialized nations. The first is in establishing internal links and effective communications among different science, technology, and industry groups in China. Although PRC officials are making progress toward implementing a national innovation system, the civilian S&T sector remains plagued by excessive bureaucracy, undermining top-level efforts to coordinate and implement modernization policies. There is also too little coordination between development goals set by China's industry-based ministries and the Ministry of Science and Technology, which oversees the majority of S&T plans discussed in Chapter Three. Oftentimes, their goals are at odds given the fact that some ministries (including the Ministry of Information Industry) still have a financial stake in the industries they oversee. Without a more objective approach to reform as well as closer communication and coordination among key stakeholders, China's scientists and industry leaders will remain two separate and isolated

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[14] Interview with a manager of a Chinese startup enterprise in Shenzhen, PRC (November 2002).

[15] According to a recent study by RAND, China remains at least five to ten years behind the state of the art in both the microelectronics and telecommunications sectors. Roger Cliff, *The Military Potential of China's Commercial Technology* (Washington, DC: RAND, 2001), 11–19.

communities. Even several hundred foreign-invested R&D centers cannot fill this void.

The other area where China's S&T modernization efforts have not penetrated effectively is in the defense industrial sector. While there is evidence of successful defense conversion efforts (re-directing defense industry production lines to commercial items), there is scant apparent evidence of the reverse, despite increased access to more advanced commercial technology and know-how gained through R&D and other high-tech investments. Given US export controls and continuing Tiananmen-era sanctions, which restrict (if imperfectly) certain types of technology sales and collaboration, it is difficult to determine whether China's relatively poor defense industrial capabilities are due primarily to the latter policies or, more likely, to a still-isolated defense S&T system.

Nevertheless, as the success of Legend and other new Chinese high-tech enterprise demonstrate, the PRC has come a long way in a relatively short period of time. There is little doubt that China's new high-tech companies have learned a great deal by partnering with foreign multinationals in R&D and other capacities. The question is: have they learned enough? This is where the trend toward R&D in China might play an interesting role in the future development of Chinese high-tech competitors, as discussed below.

The Impact of Foreign R&D on China's Technology Development Strategy

Continued high-tech offshore R&D in China, though influential on China's economy, will not necessarily hasten the rise of domestic competitors. As the evolution of R&D investments in China shows, more high-tech R&D today is taking place in wholly foreign-owned enterprises, which typically enjoy greater control over the management and intellectual property of their centers. This contrasts with the second (mid- to late-1990s) phase of R&D investment, when foreign investors were required to partner with Chinese enterprises. As a result, much of the "R&D" conducted during the latter period proved to be little, if any, "R" or "D." Mutual frustration on the part of Chinese and foreign R&D partners over the absence of genuine collaboration or research results led many foreign JV partners eventually to consolidate, transform, or terminate these mostly "show R&D" ventures.

For Chinese researchers working at the early JV-based R&D centers, the recent shift to wholly foreign-owned R&D enterprises is a welcome move since, in the end, the research work many had been doing at JV ventures proved unsatisfying. Oftentimes, the foreign partner would task only select or partial research projects to the China-based lab, thereby shrouding (deliberately or not) the fuller research process.[16] Chinese university researchers hired under contract voiced the same complaint. Thus, when Chinese access to high-tech R&D appeared greatest—under a joint R&D structure—it was often insufficient to effectively transfer the full technological know-how desired by the Chinese partner (with, no doubt, some exceptions). Today, under the growing number of WFOE-based R&D centers, Chinese researchers might have fuller access to the overall R&D process, but foreign investors also have greater control over their intellectual property and management of their wholly owned center.

This issue goes to the heart of China's persistent dilemma—how best to leap ahead in its modernization in order to catch up with the West. A key aspect of China's modernization strategy today is to acquire advanced technologies and know-how via foreign-funded R&D programs. But the debate continues among Chinese leaders over whether to acquire as much technology and know-how as fast as possible (and presumably to absorb and assimilate it all later), or to take a more slow and deliberate path to modernization by investing the time needed now to absorb and assimilate Western technologies, innovative processes, and other technological know-how already acquired and then use this knowledge and comprehension of high-tech processes to accelerate China's development and catch up to the West down the road. There are signs that both of these strategies are being implemented today. But which one ultimately prevails will impact China's technology development trajectory for many years to come.

It is not yet clear which approach is favored by China's new leadership, which took office in March 2003; the world will have to wait to see in which direction they point China's next phase of modernization. It may be telling, however, that the Chinese Academy of Sciences' latest technology development program appears to emphasize the former approach, which emphasizes focusing on acquiring advanced technologies in order to leap-ahead, as favored by former President Jiang Zemin.[17]

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[16] This is one reason why Chinese researchers are beginning to work for Chinese start-up enterprises. Working at a Chinese-owned enterprise allows them to participate in the entire research and development process, which many have learned through their work in Silicon Valley and elsewhere.

[17] According to anecdotal information, China's leadership under Jiang Zemin favored the leap-ahead strategy while many leading Chinese scientists have advocated the go-slow, invest-in-the-future approach. Conversation with leading Chinese scientist, Beijing (July 2002).

If China's leadership has decided on an accelerated acquisition approach to technology development, it represents an inherently risky strategy. In other words, if the main objective of China's open door to high-tech R&D is to pull in as much technology, know-how, and advanced equipment as possible, in as short a time as possible, foreign investors arguably now have more control over their investments in China under the WFOE structure and could do more to slow these efforts.[18] This approach also will raise concerns among foreign government officials, which could lead to increased regulatory restrictions on high-tech trade with China. More directly, the greater the pressure placed on foreign investors to transfer core technology, the more likely the foreign business community is to balk at technology transfer demands. Although this generally appears not to have been the response in years past, there is arguably more at stake for foreign firms at the R&D level of the value-added production chain, both in terms of competing in the China market and with regard to the foreign investor's global market interests. The global leverage now provided by the WTO also could be used to counter demands by PRC officials to transfer advanced technologies and know-how in return for market access.

Perhaps more importantly, foreign business executives are beginning to appreciate China's emerging high-tech acumen. A cursory review of the titles from recent US Chamber of Commerce and industry association events in China shows growing interest and some concern about emerging high-tech competition from PRC enterprises. Foreign firms also are beginning to take more direct action against IPR infringements, as recent civil suits in US and Chinese courts demonstrate. For instance, the US telecom company, Qualcomm, is suing Datang Telecom in US court for IPR infringement; Cisco Systems has sued Huawei over copied telecommunications switching equipment; and Microsoft recently won its case in Chinese court against Shanghai Huahai Computer Co. for copyright infringement. As more Chinese firms seek to export newly developed technologies possibly based on know-how from foreign IPR, more legal suits are likely.[19] Because Chinese enterprises have grown more successful in exploiting foreign technology in a short period of

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[18] For example, security measures being taken by WFOE-based R&D centers today are much more evident than in the JV R&D centers the author visited a few years earlier.

[19] This dynamic already has come into play as some Chinese high-tech companies have attempted to export domestic goods based on foreign IPR. Although this activity was—and is—tolerated by many MNCs in the China market, foreign companies have begun to sue Chinese enterprises for copyright or IPR infringement once the latter seek to export pirated items. Interview with foreign R&D executive in Beijing (July 2002).

time to develop their own high-tech product lines, foreign investors have become less tolerant of IPR infringements. Yet, at the same time, PRC firms have taken US and other foreign firms to court, in one case winning a suit against Motorola for copyright infringement on indigenously developed Chinese character technology used in cell phones.[20]

A Chinese leapfrog approach to technology transfer and development also would seem unwise since WFOE-based R&D centers in China are more conducive to an incremental, assimilation-oriented approach to advanced technology development. As noted in Chapter Four, the majority of researchers employed in foreign-invested R&D centers are local hires and, in smaller numbers, returnees from abroad. Since the consolidated, WFOE-based research centers preferred by foreign investors today appear to be conducting more advanced R&D than their JV predecessors, the potential for learning and serious collaboration is likely greater now than in the past. But so is foreign management control of these centers. Given China's long-time difficulties and ongoing struggle to reform its own S&T system to more closely match Western models of innovation, the present form of R&D investment is likely to better serve China's near- and long-term interests. In other words, if China is serious about advancing domestic high-tech industry and developing a national innovation system, then more long-term and in-depth exposure to advanced high-tech R&D practices of foreign industry leaders should prove worthwhile and reap long-lasting benefits for China's overall technological development.

Alternatively, if Chinese leaders opt for the accelerated technology acquisition strategy at the expense of absorbing and assimilating newly acquired technologies, concepts, and ways of thinking, they run the risk of spooking foreign high-tech investors and repeating old cycles of foreign technology over-dependence followed by periods of imposed technological self-reliance. As in the past, this would stall China's overall technological advancement and flatten the nation's high-tech trajectory.

Additional Risks to China from Foreign R&D and Other Technology Transfers

The risk of being cut off from Western technology is, in fact, a critical concern to PRC policymakers, particularly given the United

[20] Steven J. Frank and Yin Philip Zhang, "Year of the Patent," *IEEE Spectrum* (January 2003).

States' and other nations' strategy of hedging against China over the long-term. While, as noted in the introductory chapter, US-China relations have grown considerably more positive and cooperative over the last year or so, this by no means indicates a lack of concern on the part of US policymakers about China's future course and capabilities. Rather, many officials in the Bush administration, and others in the foreign policy community, view the PRC as a possible, if not likely, future competitor and possible adversary (although this is not a consensus view). China's neighbors, too, are monitoring the PRC's actions and statements very closely for signs of changes in policy and advances in technological capabilities in both economic and military spheres. Thus, for China, the dilemma lies in how far to push the West and neighboring Asian economies for the technology and know-how the PRC needs to advance its technological modernization without alarming these same investors and government officials about China's ability to compete economically and militarily.

Not only do PRC officials fear being cut off from foreign technology, they also fear becoming too heavily dependent on it. This is not an unrealistic concern given China's still-limited indigenous high-tech capabilities and foreign investors' rapacious appetite for the China market. PRC officials also are wary of superior foreign technological capabilities and the possible exploitation of China's under-developed commercial technology and infrastructure to advance foreign commercial and security interests. One example of these concerns is the persistent fear of a rumored "back door" capability designed into Microsoft's computer operating source code that Chinese officials worry might allow the company and US government agents access to the PRC's information networks. Although many Chinese computers utilize Windows software—much of it pirated—PRC officials now advocate open-source software such as Linux for use in government offices.[21]

Another concern regarding over-dependence on foreign technology is the continuing international "brain drain" of the Mainland's most promising young students to the United States and other industrialized economies. Simultaneously, Chinese officials fear a growing "internal brain drain" of researchers moving from lower-paid state-run research institutes to the typically higher-salaried MNC research centers. Although both trends provide clear benefits to China (in terms of high-

[21] "Will Red Flag Linux Displace Microsoft 2000 in Sensitive PRC Government Offices?," *Yanchang Evening News* (January 7, 2000), translated by the US Embassy in Beijing and available online at http://www.usembassy-china.org.cn/sandt/redflvsms.html.

tech training, skills, and know-how), PRC officials are wary of allowing too many of China's best and brightest to work for foreign interests.

Despite these potential risks and concerns, however, the PRC's entry into the WTO signals China's willingness (and need) to open its economy further to foreign investment. It reflects also a belief among China's senior leadership that the Mainland will benefit more from doing so than from remaining a closed, more nationalistic economy. This is based on China's view of globalization as akin to a force of nature that must be harnessed to China's benefit.[22] Nonetheless, as Chinese policymakers work to implement the market reforms they have committed to under the WTO, foreign investors and other observers should expect PRC officials to move cautiously to ensure China's own technological and other interests are not undermined or overlooked in the process.

Managing Risks and Leveraging Rewards from Foreign R&D Investment

For China, the demonstrated and potential rewards—both direct and indirect—from foreign-sponsored high-tech R&D far outweigh the possible risks. The latter can be managed over the near-term through prudent domestic policymaking. Recognizing this, PRC leaders have identified foreign R&D investments as a critical part of China's technology development strategy, as outlined in the latest (2001-2005) Tenth Five-Year Plan:

> The ability to make independent technological innovations must be improved in the high-tech sectors which are linked to national economic lifelines and State security… International exchanges and co-operation in science and technology should be increased… *Foreign companies should be encouraged to open research and development institutions in China*, while local science and technology firms should be encouraged to conduct research and development overseas to promote the sharing of resources and information. [Emphasis added]

The benefits to China from foreign R&D investments are likely to be greater the longer officials continue to maintain an open door to foreign high-tech investment. This is essential given China's need to fully absorb and assimilate foreign high-tech skills, processes, and technologies. PRC officials will remain wary, however, of becoming

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[22] See, for instance, the discussion in Gong Chuanzhou and Ai Hua, "The Development of China's National Defense Industry in the Globalization Process," Paper commissioned for the US-China Security Review Commission (May 15, 2001), available online at http://www.uscc.gov/cndi.pdf.

overly dependent on foreign inputs and can be expected to maximize their ability to leverage these investments and to do so as rapidly as possible.

THE IMPACT OF HIGH-TECH R&D IN CHINA ON US INTERESTS

The emergence of foreign high-tech commercial R&D in China, as outlined in Chapter Two, parallels developments unfolding in other parts of the world as a result of globalization. It should not be surprising, therefore, that this activity is taking place in China, particularly given the persistent allure of China's market throughout modern history. For American companies and the US economy as a whole, there are substantial rewards as well as some inherent risks involved in conducting high-tech R&D in China.

Offshore R&D in the PRC is Part of a Global Trend Promoting US High-Tech Industry Growth

The expanding internationalization of R&D activities—including investments on the Chinese Mainland—has benefited US high-tech industry, the US economy overall, and even US national security interests in several ways.

Among the primary benefits to the US economy is the contribution made by the large number of PRC engineers, scientists, and researchers who work for American high-tech firms, whether in Beijing or Palo Alto. The level of US dependence on foreign-born researchers from China and elsewhere is demonstrated by the thousands of special H-1B visas that are issued every year to help fill positions in our nation's high-tech firms, labs, and top universities.[23] It is not yet clear how much or in exactly what form Chinese engineers working in corporate R&D centers in the PRC will contribute to the US economy. But, over time, this "brain gain" could be substantial and enhance US high-tech industry and the US economy more broadly.

Secondly, the trend in offshore R&D has served US industry and domestic economic interests by expanding and exploiting in new ways the global market for US goods and services. Although overseas R&D is not an entirely new phenomenon, its emergence in China and other parts

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[23] The US Embassy in Beijing reportedly issued over 9,000 such visas for Fiscal Year 2001. This figure is cited in "Trade and Investment," Chapter 2 in US China Commission, *Report to Congress of the US-China Security Review Commission: The National Security Implications of the Economic Relationship Between the United States and China* (Washington, DC: US Government Printing Office, July 2002).

of the developing world has opened up new investment opportunities for US high-tech industry. Additional investment prospects such as these have become critically important during a period of sluggish US economic growth, especially in high-tech sectors still struggling to bounce back from the IT industry bubble of the late 1990s. Ultimately, R&D investment overseas should help US industry maintain a competitive advantage in rapidly developing commercial high-tech sectors such as ICT-related industries and will help reduce (at least for a period of time) the overall costs of conducting commercial R&D.

Similarly, the globalization of R&D (including in China and other parts of the world) benefits US interests due to the peculiar nature of R&D in high-tech industries such as computer programming and software engineering. As outlined in Chapter Two, these more mobile industries allow for easier and faster transfer of innovative ideas and products—wherever they might arise—back to a company's corporate headquarters. As a result, there are few physical barriers to transferring the technologies and know-how that make these and other ICT-related industries grow. Since the majority of foreign R&D centers in China's ICT sector are American ventures, much of this intellectual capital is being channeled back to the United States, directly or indirectly.

Moreover, in the current environment in which high-tech industry funds most R&D activity in the United States (and in many other Western economies), the further expansion and exploitation of new markets around the world is not only vital to US industry, but has become essential also to the US defense industry, which increasingly relies on innovative commercial ("off-the-shelf") technologies in developing the US military's most advanced weapons and other defense capabilities. Given China's as yet unrealized market potential and the critical role it plays in global trade projections, US trade and investment in the PRC could contribute in this way—indirectly but perhaps substantially—to long-term US defense modernization efforts.[24] This return on investment, however, will depend on smart, informed, and careful R&D investments in China to offset the potential risks.

Furthermore, just as foreign high-tech firms establish R&D centers in the United States to act as "listening posts" and alert them to advances in US high-tech capabilities, US R&D investments in China and elsewhere abroad can play a similar role. Given US policy concerns over

[24] For a thorough discussion of this post-Cold War phenomenon, see US Department of Defense, *Final Report of the Defense Science Board Task Force on Globalization and Security* (Washington, DC: Office of the Under Secretary of Defense for Acquisition and Technology, December 1999).

China's future military and economic development, these centers could play an important role in assessing the PRC's technological development.

Thus, although foreign R&D centers are contributing to China's impressive high-tech growth and increasing technological prowess, they are contributing as much or more—under newly consolidated, wholly foreign-owned R&D enterprises—to foreign companies' high-tech development and to the US economy. Even as international R&D activities have grown in China and around the world, the United States continues to enjoy a net inflow of R&D investment. As long as the United States remains the world's most attractive, premier location for advanced military and civil technology research and development, the US economy—as well as the scientific community and defense industry—are likely to reap significant benefits from global R&D as it spreads throughout China and other parts of the world.

Foreign R&D Investments in China Also Pose Potential Risks

Despite the substantial benefits offshore R&D can provide, this activity also entails some risk to US interests. Whenever technology and know-how are transferred from one place to another, there is a *potential* for learning on the part of the recipient, whether this is the objective or not. Effective knowledge transfer, however, does not always occur and generally should not be assumed—unless one is a high-tech investor in the China market.

The reasons for this presumption are two-fold. First, as noted earlier, China boasts a large pool of talented researchers and a growing number of experienced returnees from abroad who are likely to be more capable—as well as more *quickly* able—than in most developing countries to leverage newly introduced technological advances and know-how gained through foreign-invested R&D. China not only enjoys the advantages of being a late developer, but also has the benefit of being the latest in Asia to develop its high-tech industry. China carefully studied the lessons learned by its neighbors, particularly following the Asian financial crisis in the late 1990s. As a result, it would be a mistake to underestimate the PRC's potential to quickly develop a competitive high-tech industry, particularly in ICT-related sectors. The success of Chinese computer and telecom enterprises noted earlier represents the vanguard of China's emerging high-tech industry. Although the PRC continues to confront serious systemic challenges to its overall S&T and economic development (particularly in terms of reforming state-owned enterprises and research institutes), these new domestic high-tech competitors demonstrate China's ability—with foreign technology assistance—to move rapidly up the technological ladder in these industries.

Secondly, given the still-challenging nature of the Chinese economy (which continues to be plagued by lax enforcement of intellectual property rights, corruption, unfair trade practices, and other serious economic, political, and legal challenges), foreign investors must assume some inadvertent technology transfers.[25] For this reason, many foreign investors do not import their core technologies, research, or equipment to China; however, others do, and foreign companies are persistently pressured to do so. As foreign investors delve more deeply into advanced R&D activities in China, these market challenges and the precautions taken to deter them will help determine how much risk this form of investment poses to US corporate interests and the United States' collective economic and national security interests.

There are other potential risks as well from R&D investment in China. While the R&D labs now being established in the PRC do not approach the type of innovative center one thinks of as a traditional, Bell Laboratories-type R&D program or its equivalent, these centers present at least the possibility of new technologies and innovations being developed in the PRC before they appear in the US market. This very real possibility, and the challenge it poses to US economic competitiveness in critical industry sectors, argues for a more timely, comprehensive, and effective means of measuring and monitoring high-tech R&D activities in the PRC (and elsewhere abroad). Anecdotal evidence suggests these advances are already happening. However, US data collection efforts and export control provisions are insufficient to handle this new concern.

For example, under the current "deemed export" rule (which treats the transfer of sensitive know-how as an export subject to licensing), the US government requires licenses for Chinese nationals working for

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[25] The International Intellectual Property Alliance (IIPA) estimates that over 90 percent of business computer software in China is pirated. See IIPA, *2002 Special 302 Report on Global Copyright Protection and Enforcement* (2002), available online at http://www.iipa.com/special301_TOCs/2002_SPEC301_TOC.html. Also, as the Cox Commission Report outlined, US and other foreign companies in China are subject to espionage attempts intended to advance PRC civilian and military technological capabilities. Select Committee on US National Security and Military/Commercial Concerns with the Peoples' Republic of China, US House of Representatives (Representative Christopher Cox, Chairman), *Final Report of the Select Committee on U.S. National Security and Military/Commercial Concerns with the Peoples' Republic of China*—House Report 105-851 (Washington, DC: US Government Printing Office, May 1999).

American high-tech firms in the United States. Deemed export licenses are issued for foreign employees working with certain highly sensitive, dual-use technologies—such as high performance computing and advanced lithography technology—and are based mainly on applications for special H-1B visas submitted by workers seeking employment in US high-tech industries.[26] At present, however, deemed export rules do not appear to apply to Chinese researchers who may be working on similarly sensitive technologies at US R&D subsidiaries in the PRC.[27] Although it is unclear whether any of the foreign R&D work in China yet approaches or utilizes such advanced technologies and related skills, this apparent loophole in US law could become a growing concern as foreign R&D activities in China continue to expand.

In the meantime, the deemed export rule could easily be adapted, if necessary, to apply also to PRC nationals working for US-owned R&D subsidiaries in China. There is, in fact, legislation pending in Congress that might address this concern, by expanding the definition of an export to include "a transfer to any person of an item either *within the United States or outside of the United States* with the knowledge or intent that the item will be shipped, transferred, or transmitted to an unauthorized recipient outside the United States" [emphasis added].[28] This provision

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[26] Of the 882 "deemed export" licenses issued by the US Department of Commerce in fiscal year 2001, nearly three-quarters covered Chinese nationals working in the United States. However, the current system for licensing deemed exports is outdated (although originally formulated only in 1997) and largely ineffective due to limited compliance measures and widespread ignorance among many US firms on the need to license individuals in certain high-tech sectors. For a recent review of US deemed export licensing practices and the need for improved monitoring efforts as well as other recommendations for US policy reforms, see United States General Accounting Office, *Export Controls: Department of Commerce Controls Over Transfers of Technology to Foreign Nationals Needs Improvement*, GAO-02-972 (Washington, DC: US Government Printing Office, September 2002).

[27] There is some confusion on this point since, in spirit, the deemed export rule would seem to apply to foreign nationals employed in certain high-tech R&D centers abroad; however, according to the GAO report cited above and the US Department of Commerce, the rule technically only applies to foreign nationals working in the United States (noting that equipment transfers to R&D centers abroad are covered where appropriate under the Export Administration Regulations). Yet, according to these regulations, which govern dual-use technology transfers, an export of technology or software is defined as "Any release of technology or software subject to the EAR in a foreign country" [See Part 724, section 2(i)]. Technology is considered "released" for export in cases of "(i) visual inspection by foreign nationals of US-origin equipment and facilities; (ii) Oral exchanges of information in the United States or abroad; or (iii) The application to situations abroad of personal knowledge or technical experience acquired in the United States." Bureau of Industry and Security, US Department of Commerce, *Export Administration Regulations*, section 734 (3): "Definition of 'release' of technology or software" (Washington, DC: US Government Printing Office, June 2002), 2.

[28] This language is included in the Export Administration Act of 2003 (H.R. 55) under section 2(9)(A)(ii). Also, the term "technology" appears to incorporate R&D abroad by defining the term as "…specific information that is necessary for the development, production, or use of an item, and takes the form of technical data or technical assistance." H.R. 55, section 2(12)(B)(ii).

could apply to tangible technology transfer as well as to intangibles such as R&D.

Another concern in terms of any high-tech investments in the PRC is the potential for what are mostly dual-use technologies to be diverted to military use. Although it is unclear whether China has the capacity to effectively exploit commercial technologies for military application, there is clearly an intent and interest in doing so. This, plus the fact that the PRC has announced its goal of developing asymmetric capabilities that rely on dual-use technologies, are sufficient reason to employ a cautious approach to high-tech R&D investments in China.[29]

Looking to the future, it will be important to monitor China's progress in this area for several reasons. First, ongoing S&T modernization programs such as the 863 Program are at least in part defense-oriented and involve, in some cases, participation by foreign high-tech ventures and R&D centers. Also, the skills and know-how acquired via Sino-foreign commercial R&D collaboration could be applied to military applications just as the US military is utilizing increasing amounts of commercial off-the-shelf technologies and know-how to develop better, faster, cheaper weapons and defense technologies. Another reason for caution is recent changes to China's defense industry that are intended to open the defense sector to the same forces that have re-shaped and invigorated the modernization of China's civilian S&T sector (which is, at the same time, a tacit admission of difficulties experienced in modernizing the defense sector). This spin-on development strategy is likely to prove more effective over time as the Tiananmen sanctions grow older and opportunities for trade with China in some defense-related areas increase and may become more intriguing to foreign investors as, for instance, the Beijing 2008 Olympics draw near.

At present, however, there is no effective means of monitoring the activities taking place in overseas commercial research labs or of evaluating the overall significance and effects of what are often real-time global transactions and collaborations. With regard to the China market, this is a particular concern given the country's uncertain future.

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[29] For a discussion of China's interest in asymmetric capabilities, see "Chapter 6: Forecasting Future Wars" in Michael Pillsbury, *China Debates the Future Security Environment* (Washington, DC: National Defense University Press, January 2000), available online at www.fas.org/nuke/guide/China/doctrine/pills2; and Mark A. Stokes, *China's Strategic Modernization: Implications for the United States* (Carlisle, PA: Strategic Studies Institute, US Army War College, September 1999), 146–148, available online at www.fas.org/nuke/guide/China/doctrine/chinamod.pdf.

Lastly, although the work conducted by foreign engineers for American high-tech labs is clearly an asset to the US economy, there is growing concern over the outsourcing of high-tech US jobs and R&D abroad, particularly during a time of economic downturn. China is likely to play an ever more prominent role in this debate due to its attractive market and comparatively low-cost labor. To protect long-term US economic interests, it is incumbent upon US policymakers to act quickly to ensure that the economy does not become overly dependent on foreign labor, whether from (or in) China or elsewhere, especially in strategically important high-tech fields such as systems integration and software engineering. US government-funded efforts also are needed to educate and re-train American workers in order to alleviate this dependency and to create more technologically advanced, high-wage jobs at home as well. These and other measures will become even more vital as foreign nationals are drawn to the growing range of high-tech opportunities that are emerging in their own developing markets due to the impact of globalization.

PRC Development of New High-Tech Standards Bears Watching

An area that is beginning to gain more attention and poses the most serious potential risk to long-term US competitiveness is the issue of high-tech standards. The PRC's current Tenth Five-Year Plan (2001–2005) explicitly calls for more domestically produced high-tech goods and standards, areas in which China already has begun to make progress. In particular, Chinese enterprises are working with foreign and domestic partners to devise new-generation technology standards in areas as diverse as digital versatile discs (DVDs), high-definition television (HDTV), computer software (utilizing Linux's open source code), integrated circuitry, telecommunications switch equipment, and a new third-generation (3G) wireless standard.

Foreign technology transfers—particularly in the form of R&D—have played a critical role in China's growing capacity to develop new high-tech standards. During the interim period of foreign R&D investment in China in the mid- to late-1990s, a number of high-tech MNCs conducted joint research and development work with Chinese partners that involved systems integration and R&D to adapt technological standards. This was generally done to meet Chinese regulations requiring technology imports or newly developed products to be made compatible with PRC technical specifications, which added incentive for Sino-foreign technology collaboration. Conducting this type of R&D work, however, requires in-depth knowledge of the underlying technology or, in the case of computer software, program source code. Some foreign high-tech firms transferred this knowledge to their Chinese partners, while others did most or all of the systems integration work themselves.[30] Either way, the PRC gained substantial knowledge and/or a technical advantage that could be leveraged in developing a competitive presence in the local market, and possibly beyond.

Although largely a thing of the past, this practice raises serious economic and security concerns for US interests. First, at the time this activity was taking place, the prime motivator for conducting R&D work of this sort in China was not local market dynamics per se, but rather corporate efforts to appease regulators demanding foreign technology transfers as a condition for future market access. In other words, R&D was the price for entry into China's then-highly restricted market. Nonetheless, many of the world's leading high-tech firms complied with these demands.

Secondly, this type of overseas R&D, and in some cases collaborative R&D, was often conducted as part of sales to, or under contract with, Chinese government ministries or state-run enterprises, providing in many cases direct improvements to China's governmental infrastructure. Since much of the R&D work involved adapting foreign technology to be compatible with PRC standards and existing technologies (rather than replacing Chinese infrastructure), this activity has likely expanded China's potential to build on its current technological base using commercial off-the-shelf equipment (while at the same time enhancing future foreign investment opportunities). Finally, the transfer of this type of advanced technological know-how—which represents US high-tech firms' key competitive advantage—would likely not have been shared with Chinese partners but for the joint venture R&D requirement that existed at the time.

While systems and standards integration work is a normal part of international high-tech business, in this case, it likely conveyed to Chinese partners—and potential future competitors—a good deal of technological know-how that local enterprises probably would not have had access to otherwise or been able to develop independently. Since these capabilities are dual-use in nature, the transfer of systems

[30] At least one major foreign software company allegedly shared its source code with Chinese partners in order to develop Chinese-language software programs, according to an interview with a Chinese university-based researcher involved in software development work for foreign software company clients (Shanghai 1998).

integration skills potentially could prove useful to China's defense industrial efforts as well.[31]

Recognizing that developing purely proprietary standards imposes substantial long-term costs, Chinese officials today are pressing both foreign and domestic high-tech firms to develop new technologies for the China market that are compatible and interoperable with other international commercial technologies and standards. Due in part to the type of R&D collaborations that took place in the mid- to late-1990s, Chinese high-tech enterprises are increasingly able to meet this challenge independently. Another consequence is that high-tech firms in China have begun to develop not only innovative technologies but also new technology standards that are unique to the China market (though, at the same time, are compatible with foreign technology). In the near-term, this strategy will aid China's efforts to capture its domestic high-tech market; over the longer term, the goal is to export Chinese technology standards to the rest of the world.[32] If successful, these efforts will provide the PRC with an important competitive advantage not only in terms of the China market, but also in the global environment.

The telecommunications sector is the best example of this approach and holds the most promise for China to leap ahead of foreign competitors technologically in the near and long term. Despite initial skepticism on the part of foreign industry experts, the Chinese telecom company, Datang, has developed a new 3G standard that is causing considerable concern among foreign investors, both for the precedent it

[31] According to Eric McVadon's analysis, "Success for the PLA… has been extremely elusive in areas where integration of systems and technologies is required." Eric McVadon, "Systems Integration in China's People's Liberation Army, in" *The People's Liberation Army in the Information Age*, CF-145-CAPP/AF (Santa Monica, Calif: RAND, 1999), 217. Also, As James Mulvenon and Thomas J. Bickford point out, "Despite the fact that China has placed considerable effort into developing its own telecommunications technology, such as PLA investment in research facilities at Xidian and other universities, China continues to rely on foreign sources for equipment, parts and expertise. Indeed, many of the telecommunications technologies involved in these deals can be used to improve the military's C4I infrastructure." See James Mulvenon and Thomas J. Bickford, "The PLA and the Telecommunications Industry in China," *The People's Liberation Army in the Information Age*, CF-145-CAPP/AF (Santa Monica, Calif: RAND, 1999), 255.

[32] That this activity represents a deliberate strategy on the part Chinese officials and high-tech enterprises was confirmed through numerous interviews with foreign high-tech investors, R&D managers, and other foreign and local experts in China during the summer and fall of 2002. For an excellent discussion of this and related issues, see Barry Naughton and Adam Segal, "Technology Development in the New Millenium: China in Search of a Workable Model," MIT Japan Program, Working Paper 01.03, Revision of the paper presented to the second meeting of "Innovation and Crisis: Asian Technology after the Millenium," Cambridge, September 15-16, 2000 (May 28, 2001).

might set for China as a standard-bearer in the global telecom market and for how it came about.[33]

By working in collaboration with its foreign partner (Siemens AG), Datang has developed a new, proprietary 3G standard on which it claims to hold intellectual property rights. Known as TD-SCDMA (which stands for time division-synchronous code division multiple access), this advanced wireless technology rivals 3G standards being developed by the leading foreign competitors: Qualcomm's CDMA-2000 technology as well as the European and Japanese 3G standard (wide-band or W-CDMA).[34] Citing IPR infringement on its existing CDMA standard (which Datang is alleged to have merely adjusted and then claimed as a new innovation without paying royalties), Qualcomm is suing the Chinese company in court. Nonetheless, late last year PRC officials gave formal approval to Datang's new standard, to the surprise of many foreign investors.

But China's new indigenous telecom standard is not only potentially competitive in the China market. In 2000, Datang's 3G technology also was accepted as one of three mobile standards by the International Telecommunications Union, and in 2001 it was included as part of the international 3rd Generation Partnership Project (3GPP). Consequently, although foreign investors and industry experts have long criticized Datang's efforts and dismissed the upstart company's chances of success, they are now taking the Chinese company and its capabilities more seriously.

While PRC officials have yet to announce their final choice on which 3G standard(s) they will deploy, it now appears certain that Datang's technology will be among those selected for license approval. As a result, foreign and domestic telecom providers are rushing to adapt their product lines to be compatible with TD-SCDMA technology as well as with the other competing standards.

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[33] Bruce Einhorn, "China Aims to Close Its Technology Gap with Korea and Japan," *Business Week* (April 10, 2003), 54.

[34] The joint development that led to the new standard was achieved through collaboration begun in 1998 between Siemens AG and the Chinese Academy of Telecommunications Technology (CATT), which is affiliated with the Ministry of Information Industry and is Datang's predecessor. The TD-SCDMA mobile standard combines Time Division Duplex (TDD) technology with CDMA capabilities, providing more efficient use of available bandwidth and allowing users more flexibility in terms of applications. More importantly, it is compatible with both existing GSM and CDMA technologies. See Siemens AG, *White Paper TD-SCDMA in China* (2001).

Given the regional and global stakes involved in Beijing's selection of its next-generation telecom technology (with potential users in the China market alone estimated at up to 250 million by 2005), the decision on which 3G technology to employ will be a bellwether for China's 21st century technology strategy, as well as an indication of the role foreign high-tech investment in R&D might play in this development. In a sign of possible things to come, the German telecom firm, Siemens AG—Datang's foreign partner—announced following Beijing's formal approval of the new TD-SCDMA standard that it was moving the company's global product quality control research operations from its former base in Hong Kong to Shanghai. The reported purpose of this shift in operations is ". . . to design mobile phones specially for mainland consumers instead of copying European handsets."[35]

Although China's development of new high-technology standards is not a threat in itself, the rapid exploitation through R&D collaboration of foreign technology and know-how for the express purpose of developing new high-technology standards for the China market and the global economy is cause for concern among US and other foreign investors. Not only could this practice quickly negate the comparative advantage held by US and other high-tech investors in China, but it affects their competitive position in the global market as well due to the size and impact of the Chinese economy on global trade. A common concern among foreign investors in China is that "whoever wins the China market also wins the world."

Therefore, the example of Datang's new telecom standard is instructive and its evolution should serve as a cautionary tale to foreign high-tech investors in China. High-tech standard setting for both the local and global market is clearly China's intent; foreign investors (and policymakers) must be alert to this objective when considering high-tech collaboration with Chinese partners in the future.[36]

At the same time, however, it is important to note that the risks from this type of R&D collaboration with Chinese partners probably were highest under the joint R&D ventures formed during the mid- to late-1990s period of investment. These risks may have lessened since due to

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[35] This comment is attributed to Siemen's senior-vice president for Asia Pacific, Ray Yam, in "Siemens to Shift Mobile Phone Base to Shanghai," *Hong Kong Weekly Standard* (June 26, 2002).

[36] See "Summary of the Tenth Five-Year Plan (2001-2005)—Information Industry,“ specifically section 3: The Tenth Five Year Plan, part 6.10, translated by the Telecommunications Research Project at the University of Hong Kong, available online at http://www.trp.hku.hk/trp/infofile/china/2002/10-5-yr-plan.pdf. The author thanks the Program's Director for pointing to this resource and for providing other useful insights.

the shift in many R&D investments to wholly foreign-owned enterprises. Due to WTO reforms, foreign investors are no longer required by law to work with Chinese partners on R&D or to establish R&D centers as a condition for market access (although this is still encouraged). Moreover, while both the joint venture and WFOE models involve a transfer of technological know-how to mostly locally hired staff, there is an important distinction between conducting R&D with a joint venture partner—who shares equally in any IPR resulting from R&D collaboration—and similar work conducted under the WFOE structure. In the latter case, the IPR remains solely that of the foreign investor, who now has greater recourse in the event of IPR infringements in China (and an option short of having to dissolve the venture entirely if serious concerns arise). Thus, much of the damage and the potential risk from this type of technology transfer might already have passed.

Weighing the Risks and Rewards of R&D in China from the US Perspective

Given the more manageable. preferred form of wholly foreign-owned R&D investment in China and the beneficial effects possible in a global economy (as outlined in Chapter Two), the rewards from high-tech R&D investments in China appear at present to outweigh the potential risks to US interests. But how risky these activities ultimately are depends largely on decisions made by individual corporate executives and R&D enterprise managers. Collectively, their decisions and any risks they take will matter to the US economy, particularly in critical high-tech sectors. Over time, unwise R&D investment decisions could adversely impact US competitiveness and interests in other areas as well, including development of defense-related technologies. Therefore, it is imperative that both US industry executives and policymakers have the data they need to make well-informed decisions on high-tech R&D investments in China.

At present, this data is sorely lacking (according to one estimate, existing data captures no more than 5-10 percent of all global R&D alliances); even less data is available on R&D activities in developing counties such as China. As long as this situation persists, US executives and others could be taking greater risks in China than they know and only become aware of troubling dynamics after they have already taken hold and any damage already has been done.

IMPLICATIONS FOR US-CHINA RELATIONS

Foreign R&D investments in China are part of a global movement toward increasingly internationalized high-tech commercial innovation. In this sense, high-tech R&D in China is no different than foreign R&D investments occurring elsewhere around the globe. The PRC is distinct, however, in that the United States and other countries remain particularly wary about China's long-term capabilities and intentions, both in economic and military terms. Given these concerns, the emergence of high-tech R&D in China poses a particular challenge for US-China relations.

As a result of the PRC's enormous population, rapid economic growth, and increasing technological capabilities, modern China's economic, technological, and defense capabilities are variously compared today to both industrialized and developing nations. Comparisons such as these leave an ambiguous impression of a glass half empty or a glass half full, depending on one's outlook on China's future. But, given China's stated intention to develop indigenous high-tech capabilities, particularly in ICT industries and global technology standards, foreign investors would be wise to assume a glass half full and to compete accordingly.

In fact, unrealistic investor expectations pose a potentially serious long-term danger to US interests and US-China relations. These expectations could be problematic in two ways. First, unless American and other foreign investors begin to view (and treat) China as a high-tech competitor today, they are likely to be surprised by the PRC's rate of advancement in commercial technologies. In terms of innovative capacity, some are already comparing China's economy to that of Japan a few decades ago rather than to neighboring South Korea, Taiwan, and other developing Asian economies.[37] Comparisons such as this are likely to grow given China's market environment. Just as there are two distinct demographic Chinas—one urban industrial, and the other rural countryside—the PRC's nascent high-tech sector is developing apart from, and at a faster pace than, the rest of China's vast economy. From this more narrow perspective, China is already (or very nearly) competitive in a number of commercial high-tech sectors and should be treated as such.

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[37] See, for instance, Ed Frauenheim, "Wireless and Systems Integration 'Key to Tech Recovery'," *Silicon.com* (March 28, 2003), available online at http://www.silicon.com/news/148/1/3509.html.

Also, it is important to recognize that the Chinese Mainland is more like the US economy than its neighbors' in that the PRC has the capacity to become competitive simultaneously across a full range of industrial and technological capabilities—from low-tech agriculture and textiles to high-tech PCs and semiconductors. Unlike Japan, South Korea, Taiwan, and other neighboring Asian economies, the PRC has far greater potential to develop technological capabilities across a broad range of industry sectors and to develop at a variable pace in different parts of the country. Not unlike the United States, China can shift technological advances westward as the burgeoning coastal areas lead the way in commercial technology innovation. In other words, the PRC is not following the "flying geese" model of development that its neighbors shared (which assumes an incremental and regionally cascading model of advances in technological development). Rather, China will become increasingly competitive in a number of high- and low-tech industries all at once. Foreign investors and China's neighbors have only recently begun to come to this realization and to deal with its implications, which will impact the level, type, and pace of future high-tech investment and trade on the Mainland and across the region. Consequently, Japan, South Korea, and others in the region recently have begun to re-think their own domestic technology and economic development strategies to cope with China's rapid commercial technology advances, particularly in the ICT sector where Chinese leaders have staked their bid to compete on par with the West.

Another ongoing concern with regard to expectations is the historical problem of over-estimating China's long-term market potential (accompanied often by an underestimation of Chinese industrial and S&T capabilities). In this case, foreign investors might dismiss the potential risks R&D investments in China pose as too distant when weighing them against possible gains from enhanced market access in the near term. For heavy industries such as automotive and aerospace that enjoy long production cycles, an over-optimistic assessment of foreign market potential still allows some room for correction, if necessary. In ICT industries such as computer software or telecommunications applications, however, the production and innovation cycles are much shorter and thus entail greater potential near-term risk. As a result, there is little room for mistakes or time to absorb lessons learned. The introduction of advanced R&D activities will only hasten the development cycle of these industries in China and increase the potential for miscalculation.

For these reasons—and to avoid inadvertent damage to US-China relations—corporate executives and US policymakers alike require access to systematic and regularly updated data on overseas R&D activities in the PRC and elsewhere. Without an informed understanding of this rapidly developing trend, foreign investors and analysts are much more likely to take risks and to over- or under-estimate China's future technological trajectory. Over time, this could undermine bilateral relations as policymakers on either side seek to rectify a perceived imbalance in high-tech trade. For example, uncertainties over the extent and net impact of R&D investments in China will only exacerbate concerns over the US trade deficit with China, which exceeded $103 billion in 2002.

If either extreme scenario unfolds—investor expectations that are too cold or too hot—relations with China will suffer, as they have in the past when foreign business interests have departed the market en masse in frustration and dismay or when US officials have grown seriously concerned over corporate investment activities abroad. In either case, both China and the United States would lose the rewards each enjoys from overseas R&D investment, as would the regional and global economy.

Thus, the United States and China share a common interest in ensuring that high-tech R&D investments serve the political, economic, and security interests of both sides. For each, foreign high-tech R&D activity in China poses risks but, at the same time, substantial rewards. As long as globalization remains a driving force in international relations, the United States and China can both gain from this activity. Managing the inherent potential risks involved, however, will pose a continuing challenge for policymakers in both countries. One way to help illuminate this trend and alleviate concerns in Washington and Beijing would be to cooperate on collecting R&D data—both on US R&D investments in China and R&D-related PRC investments in the United States.

Furthermore, improved transparency into Chinese policies and government functions—particularly in the area of civil-military relations—would also help alleviate some US concerns over advanced R&D investments in China. In recent years, China has expanded transparency into its economic and technology development efforts and, to a limited extent, its military strategy and objectives. Similarly, greater insight into China's evolving defense industrial sector reforms and military modernization plans—as well as the possible contributions made by foreign investment and R&D to these efforts—could help ease US technology transfer concerns. Moreover, ongoing bilateral exchanges conducted under the aegis of the US-China Science and Technology Cooperation Agreement could address these issues and provide greater confidence on both sides that foreign R&D investments in China are mutually beneficial.

In the meantime, China's recent WTO membership and commitments to further open up its market to fair competition have allayed some worries about China's future course, despite foreign investors' continued frustration in a number of areas. However, the next few years—as China demonstrates its commitment *and* capability (or not) to fulfill its pledges—will be critical. If China succeeds in these efforts, foreign R&D investments will likely grow and the country's overall high-tech development trajectory will continue to move upward, perhaps very sharply (at least on the commercial side). Yet if China is not able or willing to fulfill its obligations, foreign investment will lag (including in R&D) and slow China's high-tech ascent.

Although it is for different reasons, US and PRC interests both lie in reaping the rewards from R&D in China while reducing the risks. To do so successfully will require significantly better information about this growing trend and an understanding of its effects on the Chinese economy. This report has illuminated only the outlines of this important new dynamic in US-China relations. Much more analytic work will be necessary to fully understand the implications this trend holds for the United States, for China, the region, and the global economy.

RECOMMENDATIONS FOR US POLICY

A number of policy implications follow from the observations and analysis outlined above. In order to develop a better understanding of foreign high-tech R&D in China and to manage the potential risks to the US economy, national security interests, and relations with China (and the region), policymakers should consider implementing the following policy recommendations:

- ***Develop a more comprehensive method of collecting data on high-tech R&D activities abroad and implement the system as soon as possible***. A much greater effort is needed to provide policymakers and business executives with a clearer, more comprehensive, and timely picture of global R&D activities. To gain a deeper understanding of the impact these activities are having on the US, Chinese, and global economies, annual statistical data—utilizing the newly defined NAICS codes—is essential and must be coordinated with other countries. Although the US National Science Foundation, Bureau of Economic Analysis, and the Bureau of the Census have signed a Memorandum of Understanding to pool their statistical resources in order to track global R&D activities (based on existing reporting requirements on US companies), this effort has been too long in the planning stages and should be approved, funded, and implemented as soon as possible. High-level attention by US government officials is needed to bring these efforts to fruition.

- ***Add information exchanges on high-tech R&D activities to the agenda of meetings held under the US-China S&T Cooperation Agreement***. Chinese officials and academics are as interested in analyzing and quantifying the growing global R&D trend as are US officials, business executives, and analysts. Over the past year, in particular, analysts in the PRC have conducted a number of surveys to try to determine the actual number of foreign-funded R&D programs in China. In addition, China now enjoys observer standing in the OECD, where studies on global R&D investments also are under way, and the US and Chinese National Science Foundations are cooperating on standardizing collection of statistical data. The present, therefore, seems an opportune time to establish a bilateral (or multilateral) system for tracking data on international R&D investments in China. The United States and the PRC have much at stake in understanding these activities and both would benefit from more precise and regular collection of data. The bilateral S&T Cooperation Agreement could provide a positive atmosphere, near-term opportunity, and official umbrella under which to conduct, or at least begin undertaking, a joint effort such as this.

- ***Amend the deemed export rule to cover advanced foreign R&D investments in China; over the longer-term, reform the US export control system to better monitor global R&D and other newly emerging international business dynamics***. The present US system of export controls is by all accounts too slow, too outdated, and too cumbersome to be effective in a global economic environment. Designed to meet Cold War concerns, the system has become nearly obsolete in dealing with the more dynamic, fast-paced, and variable world in which we live. Nor can the present US export control system effectively capture the types of technology and knowledge transfers that are taking place as part of foreign R&D investments. Despite any number of non-governmental studies, expert panels, and government-led efforts on how to reform US export controls, very little has been achieved.

A near-term solution, however, exists that would address immediate concerns over potentially critical technology transfers through R&D activities in China: amending the current deemed export rule to cover technology transfers occurring outside the United States. Whether included as part of the Export Administration Act or in other legislation, this apparent oversight in US law should be corrected as soon as possible. Over the longer-term, significant reforms are needed to the US export control system to effectively monitor international R&D activities—both in China and in the United States.

A new monitoring mechanism, however, does not imply more onerous export control provisions, but instead would require adopting a more flexible system and business-oriented model of implementing export controls (in other words, creating an interim option between full export licensing or complete decontrol). A monitoring system to track transfers of sensitive technologies and know-how abroad could be developed utilizing modern ICT capabilities to ensure an efficient and time-sensitive process as well as greater transparency and accountability of US R&D-related investments in China and elsewhere. To achieve this objective, senior Executive Branch officials—representing the White House or National Security Council—must make reforming the export control process a top priority and consult with both Congress and industry to develop a workable system. The Bush administration stated upon coming into office its intention to reform export controls to meet 21st Century challenges. The advent of foreign high-tech R&D in China poses just this sort of immediate and long-term challenge. To ensure that US economic and security interests are being met as high-tech R&D moves further offshore, export control reforms must be made a priority and be given the high-level attention this concern warrants.

- ***Increase US government investment in basic research and education in order to maintain the United States' global lead in critical high-tech industries and innovation.*** Current government funding for R&D in the United States is holding steady, but this is due only to concerted efforts and support from Congress. US policymakers must not sacrifice funding for science and technology to other priorities such as homeland security; both are essential to long-term US national security interests. Funding levels must also increase over time if the United States is to remain economically, technologically, and militarily competitive. The PRC is not alone in adopting multi-year strategies to achieve high-tech advances; Europe, Japan, and other states and regions are competing for a greater share of the world's high-tech market. In an increasingly global environment, these efforts are likely to be more successful, much more quickly, than in the past. As other nations and regions move up the technological ladder, however, many of the foreign nationals supporting US labs, universities, and high-tech companies will begin to find similar work in their own economies. Thus, to ensure US competitiveness over the long term, policymakers must invest more in grade school and secondary education, particularly in basic sciences, mathematics, and engineering, or risk the United States falling behind in critical advanced technological capabilities vis-à-vis the PRC and other emerging high-tech competitors.

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