

Unleashing India's Innovation

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Toward Sustainable
and Inclusive Growth

Mark A. Dutz, Editor



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Foreword

The goals of this book and the collaborative process underlying its preparation are to develop concrete actions that strengthen India's innovation environment, enhance productivity growth, and reduce poverty. Because innovation is a broad topic, this volume covers a vast array of areas ranging from India's broader economic and institutional regime—with a priority on promoting stronger competition among enterprises to unleash innovation—to more specific areas, such as

- formal research and development (R&D) and intellectual property rights (IPR);
- foreign investment and technology transfer;
- grassroots innovation;
- metrology, standards, testing, and quality services;
- education and skills;
- telecommunications infrastructure and high-speed research networks; and
- early-stage technology development finance and venture capital.

The book also offers many recommendations. Implementing them will require actions by many ministries, as well as by the private sector and civil society. For technical and political reasons, not all the recommendations have the same priority or are as easy to implement. Many have different time horizons. Some require changes in policies and regulations. Others involve redeploying existing resources. Still others require additional public and private resources. In addition, many of the changes will have greater impact if there is coordination and appropriate sequencing, because many are interdependent.

Thus, this volume should be viewed as a first step toward bringing together the many elements that need to be addressed for India to develop an innovation economy. The next step should be developing a realistic implementation plan that sorts through the different priorities and sequencing of what is feasible given India's complex economy. This would best be done by a task force of Indian policy makers working with business and social leaders.

In addition, efforts should be made to raise public awareness of what is at stake for India in light of both the rapidly changing and demanding international environment and the country's needs and potential. The World Bank Group stands ready to work with Indian counterparts on the issues raised in this book to help generate concrete results.

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Abbreviations

Rs	Indian rupees. The conversion to U.S. dollars is roughly 41 Rs to US\$1.00.
\$	Unless otherwise designated, this symbol refers to U.S. dollars.
APIDC	Andhra Pradesh Industrial Development Corporation
ATMA	Agriculture Technology Management Agency
ATP	(U.S.) Advanced Technology Program
BIRD	(Israel–U.S.) Binational Industrial Research and Development Fund
BRICKM	Brazil, Russia, India, China, Korea, and Mexico
BYST	Bharatiya Yuva Shakti Trust
CSIR	Council of Scientific and Industrial Research
DARPA	(U.S.) Defense Advanced Research Projects Agency
DRDO	Defence Research and Development Organization
DSIR	Department of Scientific and Industrial Research
DST	Department of Science and Technology
ERNET	Education and Research Network
ESTD	early-stage technology development
FDI	foreign direct investment
GARUDA	National Grid Computing Initiative
GIAN	Grassroots Innovation Augmentation Network
GDP	gross domestic product
HBN	Honey Bee Network
HGT	Home Grown Technology program
HIV/AIDS	human immunodeficiency virus/acquired immune deficiency syndrome
ICAR	Indian Council of Agricultural Research
ICICI	formerly Industrial Credit and Investment Corporation of India, now ICICI Bank
ICMR	Indian Council of Medical Research
ICT	information and communication technology
IIMs	Indian Institutes of Management
IISc	Indian Institute of Science
IIT	Indian Institute of Technology
IP	intellectual property

IPR	intellectual property rights
ISO	International Organization for Standardization
IT	information technology
ITES	information technology-enabled services
MNC	multinational corporation
MSE	micro and small enterprise
MSME	micro, small, and medium enterprise
MST	Ministry of Science and Technology
MSTQ	metrology, standards, testing, and quality
NASSCOM	National Association of Software and Service Companies
NGO	nongovernmental organization
NIF	National Innovation Foundation
NMITLI	New Millennium Indian Technology Leadership Initiative
NRDC	National Research Development Corporation
NREN	national research and education network
OECD	Organisation for Economic Co-operation and Development
PCT	Patent Cooperation Treaty
PPP	purchasing power parity
PRDSF	Pharmaceuticals R&D Support Fund
R&D	research and development
SBIR	(U.S.) Small Business Innovation Research program
SBIRI	Small Business Innovation Research Initiative
SIRO	scientific and industrial research organization
SME	small and medium enterprise
SPREAD	Sponsored Research and Development program
SRISTI	Society for Research and Initiatives for Sustainable Technologies and Institutions
SSTP	State Science and Technology Program (State Councils)
TDB	Technology Development Board
TDDP	Technology Development and Demonstration Program
TePP	Techno-entrepreneurs Promotion Program
TFP	total factor productivity
TCGA	The Centre for Genomic Application
TIFAC	Technology Information Forecasting and Assessment Council
TKDL	Traditional Knowledge Digital Library
TRIPS	Trade-Related Aspects of Intellectual Property Rights
WTO	World Trade Organization

Executive Summary

India is increasingly becoming a top global innovator for high-tech products and services. Still, the country is underperforming relative to its innovation potential—with direct implications for long-term industrial competitiveness and economic growth. About 90 percent of Indian workers are employed in the informal sector, and this sector is often characterized by underemployment, as well as low-productivity and low-skill activities. Although India has the benefit of a dynamic young population—with more than half of the country’s population under 25 years old—only 17 percent of people in their mid-20s and older have a secondary education. To sustain rapid growth and help alleviate poverty, India needs to aggressively harness its innovation potential, relying on innovation-led, rapid, and inclusive growth to achieve economic and social transformation.

One of the unique features of this book is its focus on inclusive innovation—that is, knowledge creation and absorption efforts most relevant to the needs of the poor in India. This is in addition to the book’s emphasis on how faster growth can be facilitated by promoting “new to the world” knowledge creation and commercialization—the traditional understanding of the term *innovation*—as well as through often underappreciated but even higher-impact “new to the market” diffusion and absorption of existing knowledge.

To unleash its innovation potential, India needs to develop a three-pronged strategy:

1. India would benefit from increasing competition as part of efforts to improve the investment climate, supported by stronger skills, better information infrastructure, and more finance—public and private.
 - *Competition is vital to unleash innovation.* India must encourage stronger competition among enterprises. Since the Indian economy was opened up in 1991, the private sector has invested the most in research and development (R&D) in the sectors most open to competition. In 2004, enterprise R&D was more than seven times higher than in 1991. Recommended actions to spur competition include removing nonessential regulations and applying essential ones more transparently in product, land, labor, capital, and infrastructure services markets—for example, easing limits on small industries, restrictions on foreign direct investment (FDI), and barriers to import competition, as well as introducing bankruptcy reforms and modernizing the Industrial Disputes Act.

- *Limited skills and training are a major bottleneck.* Only 16 percent of Indian manufacturing firms offer in-service training, compared with 92 percent in China and 42 percent in the Republic of Korea. The Indian firms that provide in-service training are 23–28 percent more productive than those that do not. Moreover, gross enrollment in higher education is only 12 percent in India, compared with 90 percent in Korea and 68 percent in the Russian Federation. The skills bottleneck could be unblocked by providing public matching funds for firms to invest in training, increasing the fiscal and managerial autonomy of universities and colleges, and increasing private participation in higher education.
 - *Better information flows are needed.* India is already the world's fastest-growing market for mobile phones, with the number of wireless subscribers jumping 55 percent in 2006. However, disparity persists between rural and urban areas: teledensity is 40 percent in urban areas and just 4 percent in rural areas. And while high-speed national research and education networks accelerate the pace of new discoveries and the expansion of knowledge, India's connectivity is less than 1 percent of China, Korea, the United States, and European Union countries. Information-related actions could include expediting the allocation of radio and wireless broadband spectrums, increasing targeted subsidies for rolling out rural mobile and broadband, and agreeing on an organizational structure to deploy and manage a national research and education network.
 - *More early-stage funding is needed.* In 2005, just 13 percent of deals by venture capital and private equity providers were for early-stage funding. In dollar terms, early-stage deals accounted for even less of such investments: 4–6 percent. Cumulative start-up capital provided for seed financing in India is estimated to be \$25 million–\$35 million—enough for 75–100 start-ups, many fewer than the 450–600 start-ups needed. Finance-related actions could include facilitating regulations for early-stage venture capital investments, and government provision of leveraged returns for private investments in innovation areas overlooked by the market (such as rural industry and pro-poor, grassroots innovations) by creating a fund of funds—with distinct windows for pro-growth innovations and inclusive innovations—with venture capital funds managed by the private sector.
2. India would benefit from strengthening efforts to create and commercialize knowledge, as well as better diffuse existing global and local knowledge and increase the capacity of smaller enterprises to absorb it. If all enterprises could costlessly achieve national best practices based on knowledge already in use in India, economic output could more than quintuple.
- *Variations in productivity highlight the need for better knowledge diffusion.* Average enterprise productivity in finance, insurance, and real estate companies is nearly 23 times that in agriculture. But these industries account for only

1.3 percent of employment, while agriculture accounts for 60 percent. Actions to better diffuse existing knowledge could include increasing openness to trade and FDI, coupled with strengthening and expanding public support for technology at the cluster level and modernizing infrastructure for metrology, standards, testing, and quality (especially metrology). India could also consider strengthening its support infrastructure for technology licensing by creating a public-private technology acquisition fund, building on intellectual property that is already locally available.

- *Private enterprises need to increase R&D spending.* Aggregate domestic R&D spending has never exceeded 1 percent of GDP, and 75–80 percent comes from the public sector. However, between 1998 and 2003, multinational corporations spent \$1.3 billion on R&D in India—showing that its valuable assets could be exploited more effectively. Actions to spur private R&D could include consolidating and expanding public early-stage technology development programs, as well as developing a policy and action plan to use public procurement to promote innovation. Reforms to existing early-stage technology development programs could include establishing a streamlined matching grant program building on India’s Sponsored Research and Development program and Small Business Innovation Research Initiative—targeted mainly at smaller enterprises and promoting more collaboration.
- *New domestic knowledge needs to be converted to commercial use.* Of the top 50 applicants for patents in India between 1995 and 2005, 44 were foreign firms. Only six were Indian; three of these were public institutions and one, a public corporation. Just two were private Indian firms, both in the pharmaceutical industry. Actions to promote commercialization and strengthen links among industry, universities, and public laboratories could include providing support to technology transfer offices, creating a patent management corporation, developing technology parks and incubators, and improving India’s regime for intellectual property rights. India should also consider enhancing support for higher-risk technology R&D and commercialization by strengthening its New Millennium Indian Technology Leadership Initiative—including by opening the program to international collaboration and giving grants to both research institutions and private enterprises, with sharing of any resulting royalties. To further spur international collaboration, India could create a Global Research and Industrial Partnership program to promote advanced R&D and commercialization efforts conducted jointly by domestic and foreign enterprises.
- *The diaspora needs to be tapped more effectively.* About 2 percent of India’s population—20 million people—live abroad, where they earn the equivalent of two-thirds of India’s GDP. Actions to more effectively tap India’s overseas talent could include supporting a larger diaspora network, building on existing groups that aggregate this population’s talent and capital for use in India.

3. India would benefit from fostering more inclusive innovation—by promoting more formal R&D efforts for poor people and more creative grassroots efforts by them, and by improving the ability of informal enterprises to exploit existing knowledge. *Existing pro-poor initiatives need to be scaled up.* Inclusive innovation can play a critical role in lowering the costs of goods and services and in creating income-earning opportunities for poor people. The Council of Scientific and Industrial Research has developed technology applications for rural India, and university and formal private initiatives (such as e-Choupal and Amida's Simputer) have delivered benefits. The National Innovation Foundation has a repository of more than 50,000 grassroots innovations and traditional knowledge practices. And a number of initiatives exist to help the informal sector better absorb knowledge. More favorable matching grant support for pro-poor early-stage technology development could significantly increase collaboration among public R&D entities, universities, nongovernmental organizations, national industries, and global networks. Increased support for grassroots innovators could be provided to the National Innovation Foundation to scale up impact. To leverage traditional knowledge into revenue, a policy-oriented intellectual property rights think tank could propose how to implement a cheaper intellectual property regime. Finally, successful technology upgrading programs could be extended to help informal and rural enterprises make better use of existing knowledge.

The action-oriented recommendations that form part of this volume's three-pronged innovation strategy require a realistic, time-bound implementation plan. This may best be accomplished through a consensus-building process that includes a task force of Indian policy makers working with business and social leaders—who would be in the best position to set priorities among the recommendations and develop an appropriate sequencing of activities. To help capture the nation's imagination, it may be desirable to focus on “grand challenges” such as access to clean water throughout the country or mitigating road congestion in cities. A light-touch public-private oversight mechanism may be required to evaluate and address the fragmentation of India's current innovation system; encourage collaboration and facilitate streamlining of the system's constituent programs, using public-private partnerships wherever appropriate; and monitor the achievement of realistic targets, with periodic international benchmarking as India's innovation potential is unleashed. India's successes with inclusive innovation will be of particular interest to other developing and emerging market economies also seeking to harness innovation for poverty reduction and economic development.

Overview: Toward an Action Agenda for Innovation

Mark A. Dutz

India's recent growth has been impressive, with real GDP rising by over 8 percent a year since 2004—accompanied by a jump in innovative activities. Growth has been driven by rapid expansion in export-oriented, skill-intensive manufacturing and, especially, skill-intensive services. For example, pharmaceutical firms such as Dr. Reddy's Lab have been pursuing a twin strategy of profiting from the production of generic drugs and investing in research and development (R&D) to discover new ones. Growth has also been fueled by increased local demand, backed by rising urban and rural incomes, and a sharp rise in savings and investment rates. Indian manufacturers have focused on delivering low-cost products to previously untapped markets by innovating to lower costs and create new delivery mechanisms—as with Tata Motors, which has promised to deliver a car, geared toward India's middle class, priced at less than \$3,000. Thanks to its innovations in outsourcing, Bharti Tele-Ventures offers some of the world's lowest telephone prices. And innovations in supply chains have integrated those at the bottom of India's economic pyramid, as exemplified by e-Choupals. These cyber kiosks, established in thousands of villages, have given farmers the power of information—eliminating middlemen and resulting in higher productivity and better prices for farmers.

Growth, accompanied by innovations, has been associated with rising living standards and a reduced number of poor people. However, despite pockets of innovative activities in both the formal and informal sectors, innovation remains concentrated in a small segment of the economy. Roughly 90 percent of the workforce is employed in the informal sector, which is often characterized by low-productivity and low-skill activities. Productivity is also low in most formal enterprises. Given this dualism in the economy, what can be done to strengthen the likelihood of sustained high growth rates and, in particular, to address the unmet needs of the informal sector and the poor? Innovation is crucial for increasing growth and can also help reduce

poverty. By applying knowledge in new ways to production processes, better and previously unavailable products can be produced with the same or fewer inputs—to meet the needs of all sections of Indian society.

This book provides action-oriented recommendations for India to unleash existing capabilities and build on its innovation potential, to help meet the dual challenges of sustained and inclusive growth. Sustaining growth is a challenge because of both intensified external competition brought on by information and communication technology (ICT)—spurred globalization and internal pressures linked to skill shortages. As a basis for its recommendations, the volume examines the extent to which Indian enterprises are undertaking innovative activities and analyzes their enabling environment.

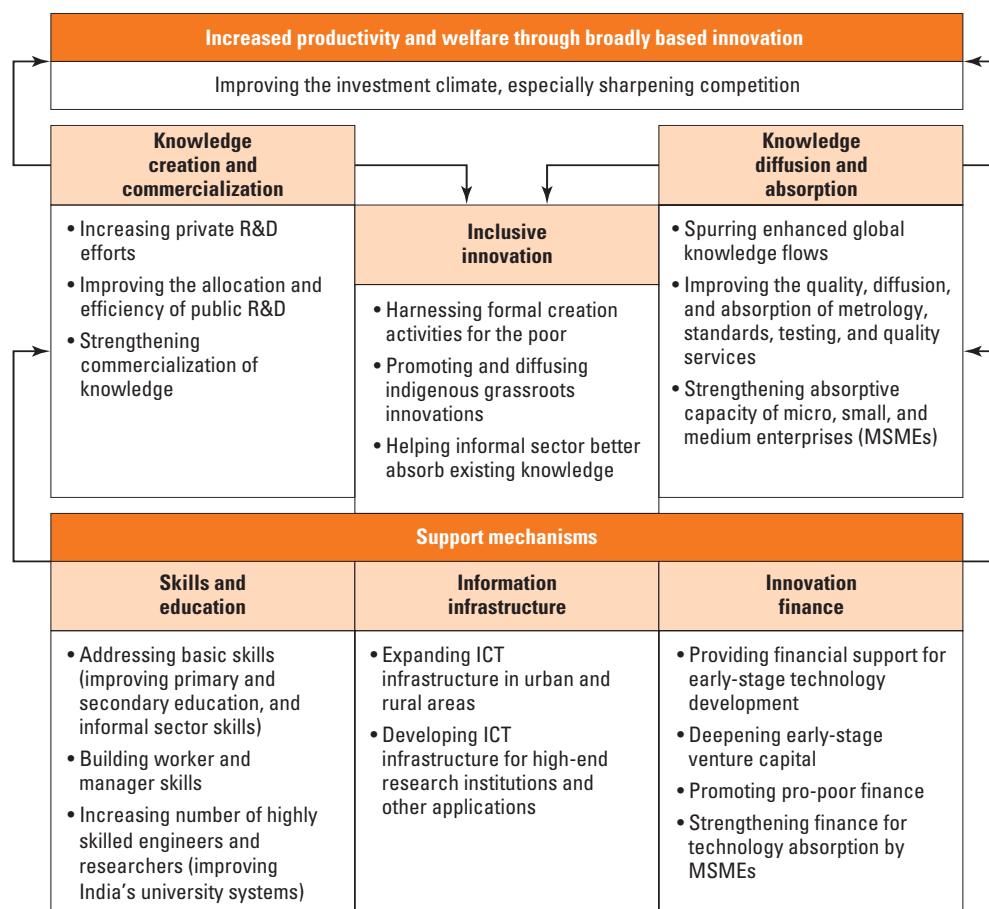
Given the dualism of the Indian economy, innovation is broadly defined to include “new to the world” knowledge creation and commercialization as well as “new to the market” knowledge diffusion and absorption. This second type of innovative activities involves enterprises applying existing technologies in new locations and product areas. Both types of activities seek to provide better, cheaper products in response to consumer needs—creating more and higher-paying jobs. Although both types of innovation activities are essential, India stands to gain more from catching up to the global frontier of knowledge through increased absorption than from trying to push out the frontier through creation. An enormous amount of existing global knowledge is not yet fully used in India. A 2006 World Bank Enterprise Survey of roughly 2,300 manufacturing enterprises in 16 Indian states found that applying existing technology in new settings is more likely to be associated with increases in productivity than are efforts to create new knowledge. In addition, given the overriding need to better address the needs of the poor in India, knowledge creation and absorption efforts most relevant for the poor are indicated by the term “inclusive innovation.”

This book has three main messages (figure O.1 shows how they are interrelated). To unleash its innovation potential, India needs to develop a strategy that does the following:

- Focuses on increasing competition as part of improving its investment climate, supported by stronger skills, better information infrastructure, and more finance—public and private.
- Strengthens its efforts to create and commercialize knowledge, as well as better diffuse existing global and local knowledge and increase the capacity of smaller enterprises to absorb it—if all enterprises could costlessly achieve national best practice based on knowledge already used in India, the output of the economy could increase more than fivefold.
- Fosters more inclusive innovation—by promoting more formal R&D efforts for poor people and more creative grassroots efforts by them, and by improving the ability of informal enterprises to exploit existing knowledge.

Recognizing the importance of generating, commercializing, and absorbing R&D, in recent years the government has created a number of support programs—but they

Figure 0.1 Unleashing India's Innovation Potential



Source: Author.

could be more effective. Public programs supporting innovation have achieved significant successes. Still, their outcomes have not been commensurate with the needs of the Indian economy or the resources invested in them. This imbalance reflects many missed opportunities. Most of the programs have been run by government institutions; private sector involvement has been minimal. The public systems, not only in India but across the globe, especially where investments are to be made, normally go through a very long and elaborate decision-making process and are generally risk averse. This bureaucratic, rigid nature—and lack of risk taking—typical of government institutions, limits the effectiveness of these programs. These programs should be subjected to regular, independent performance evaluations and international benchmarking.

A new approach is needed—one that leverages the strengths of the public and private sectors in designing and operating innovation support programs, with a greater focus on inclusive innovation. The government's role should be to provide

a policy and regulatory framework that encourages the private sector to undertake riskier initiatives that are economically beneficial but that firms would not normally undertake. Removing nonessential regulations and facilitating more transparent application of essential ones in product, land, labor, capital, and infrastructure services markets—thereby promoting fairer and more intense competition—are critical to spurring innovation efforts. Reforms that enhance genuine competition are essential. This framework should be complemented by financial support where needed, with significantly more for pro-poor innovation. The private sector should be called on to manage such programs, with appropriate checks and balances as well as performance standards and monitoring. Moreover, all public support programs should periodically receive thorough reviews by independent experts, including international ones as appropriate. Based on these evaluations and international benchmarking, public support programs should be expanded, restructured, or closed.

India could benefit from an explicit, multipronged innovation strategy—building on existing private and public innovation efforts. This volume examines key issues and offers recommendations in six areas, in addition to an initial discussion of the Indian context and enabling environment. It argues that India's innovation strategy should build on the complementarities between knowledge creation and commercialization (that is, more state-of-the-art innovation), knowledge diffusion and absorption (greater acquisition and use of existing knowledge), and more explicit promotion of inclusive innovation—all supported by strengthened skills, upgraded information infrastructure, and enhanced innovation finance. The book is structured as follows:

- Chapter 1 reviews the Indian context and enabling environment.
- Chapter 2 analyzes knowledge creation and commercialization.
- Chapter 3 discusses knowledge diffusion and absorption.
- Chapter 4 encourages inclusive, pro-poor innovation.
- Chapter 5 addresses the need for stronger skills and education for innovation.
- Chapter 6 examines ways of improving information infrastructure.
- Chapter 7 suggests approaches to enhance innovation finance.

The recommendations that form this book's multipronged innovation strategy need to be prioritized and molded into an action plan—ideally through a collaborative process. Innovation is a broad topic that cuts across government ministries and economic sectors, and affects all Indians. It requires both private and public commitments and efforts—especially collaboration between partners with different perspectives. At the government level, some policy elements and investment decisions will be federal, while others will be more state responsibilities. This volume offers a number of recommendations, many with sizable cost implications, for implementation by the government, private entities, and civil society. The Ministry

of Science and Technology is beginning to prepare a national innovation program to scale up or modify some of the ongoing initiatives discussed in this book and introduce others. In addition, India would benefit from a broader complementary effort—including representatives from government, academia, the private sector, and civil society who are in a good position to set priorities among the recommendations and consider appropriate sequencing of activities, with a possible focus on national “grand challenges” such as road transport congestion in cities or access to clean water. A bold implementation approach emanating from such a consensus-building process would then benefit from a “light” public-private oversight mechanism—one that helps address the fragmentation of the current innovation system and tracks the achievement of realistic targets, with continuous feedback and periodic international benchmarking as the program evolves.

The Indian Context and Enabling Environment

The now-famous “Dabbawala” (literally, lunchbox-carrier) system is an innovative business process that allows 4,500–5,000 semiliterate Dabbawalas to deliver almost 200,000 lunches to workers every day in Mumbai. The Dabbawalas reportedly make one mistake per 6 million deliveries. So remarkable is this delivery network that international business schools have studied the work flows of the Dabbawala system to understand the key to its stellar performance rating.

In chapter 1, Mark A. Dutz and Carl Dahlman discuss the “dualism” of the Indian economy. India’s heterogeneity—with dispersion in enterprise productivity even wider within than across economic sectors—calls for support to create and commercialize new knowledge as well as to diffuse and absorb existing knowledge, with greater emphasis on inclusive innovation. Indicators of India’s innovation capacity highlight its innovation potential. Still, India is behind the global frontier in most sectors of the economy. Thus, innovation in India should not be thought of as simply pushing out the global technological frontier in a few areas, but as improving practices across the whole economy. More inclusive innovation efforts are especially important for poor people and informal enterprises. This chapter discusses

- relevant structural features of the Indian economy;
- the book’s definition of broadly based innovation, aggregate indicators of innovation, and links between innovation and productivity; and
- the enabling environment for innovation, including the centrality of competition as the key stimulus for innovation and the need for agreed on principles for coordinating innovation support programs.

India is a heterogeneous economy, with productivity dispersion even wider within than across sectors. On the one hand, India is the world’s fourth-largest economy in purchasing power parity (PPP) as well as nuclear and space power. Moreover, it is increasingly becoming a top global innovation player in biotechnology,

pharmaceuticals, automotive parts and assembly, information technology (IT), software, and IT-enabled services (ITES).

On the other hand, India is still a largely subsistence economy, with illiteracy rates of 46 percent among women and 25 percent among men, and about a quarter of its population living below the national poverty line, with significant spatial variance across and within states. Less than 3 percent of the Indian workforce is in the modern private sector, while roughly 90 percent is in the informal sector. This heterogeneity translates into a wide dispersion in productivity levels. Productivity dispersion of formal enterprises in manufacturing sectors is wider in India than in all other major comparator countries (Brazil, China, the Republic of Korea, Mexico, the Russian Federation) except Brazil. And India's productivity dispersion is wide across both formal and informal sectors of the economy. The average productivity of finance-related businesses is 23 times that of agricultural activities. Productivity dispersion is even wider within sectors, suggesting a strong potential for productivity improvement. The least productive formal enterprises in auto components and textiles are hundreds of times less productive than the most productive firms in those sectors within the country. Such differences are even starker among informal enterprises.

The heterogeneity of the Indian economy calls for a broader definition of innovation—one that distinguishes between “new to the world” innovation (creation and commercialization), “new to the market” knowledge (diffusion and absorption), and explicit promotion of innovation to reduce poverty (inclusive innovation). India has many islands of excellence. Still, it falls behind the global frontier in most sectors of its economy. Thus, innovation in India should not be thought of as simply shifting outward the global technological frontier, but as improving practices across the entire economy. Innovative activities are not restricted to new products but include innovations in processes and organizational models. Though the recommendations have broader applicability, this volume focuses on central government support for industrial innovation—not agricultural, medical, or other innovations, or state-level support. Though based on the best available comparable data, given the pace of change in this area, reported statistics may have been overtaken by recent developments.

Indicators of India's capacity for innovation highlight its potential and the links among innovation, productivity, and competitiveness. India's stock of scientists and engineers engaged in R&D is among the largest in the world. But another critical innovation input is domestic R&D spending, which in India has never exceeded 1 percent of GDP. However, the sizable increase in R&D activity by multinational corporations (MNCs) in India since 2002 has had a significant impact on total R&D spending. Moreover, acquiring new technology has a stronger correlation with productivity than does R&D spending. By far the most important channel for absorbing knowledge is through the use of new machinery and equipment. India has a strong record in producing basic knowledge, as proxied by internationally refereed scientific and technical publications. It has also experienced a significant increase in patent applications. Overall, India appears better at producing basic rather than commercializable knowledge. Still, the efficiency of its R&D spending, as measured

by the relative costs of a scientific publication or a U.S. patent, appears higher than in comparator countries.

India's enabling environment for innovation consists of policies, institutions, and capabilities that support the creation and commercialization of new knowledge, and the diffusion and absorption of existing knowledge—for both formal and informal sectors of the economy. India could gain from incentives that encourage stronger competition among enterprises and a national mind-set that values innovation. Since the 1991 liberalization, the private sector invested the most in R&D in the sectors most open to competition. Enterprise R&D spending as a share of sales increased more than sevenfold between 1991 and 2004. However, domestic innovation efforts, R&D spending, and diffusion and absorption efforts remain low largely because competition pressures—although strengthening—are not sufficiently widespread throughout the economy. Two reforms are crucial:

- *Sharpening competition among enterprises so that innovation becomes a necessity*—for example, by reducing entry and expansion barriers such as limits on small-scale industries, and remaining restrictions on foreign direct investment (FDI) and barriers to import competition. In addition, reallocation of capital should be eased through bankruptcy reforms and modernization of the Industrial Disputes Act.
- *Strengthening innovation-friendly sociocultural norms.* To help solidify a mind-set for nationwide innovation, more resources are required to raise awareness about the high social value of business and social innovation and commercial success, to disseminate success stories highlighting the achievements of techno-entrepreneurs, and to provide high-profile innovation awards and prizes—including for creative teachers.

Creating and Commercializing Knowledge

Once characterized as producing outdated 1940s models referred to as “fossils on wheels,” the Indian automobile industry—with FDI allowed up to 100 percent and no minimum investment requirements for new entrants—now accounts for more than \$13.5 billion in investments and employs 500,000 workers directly and 10 million indirectly. India is emerging as a global center of innovative automotive design. Mahindra & Mahindra spent only \$120 million to develop its fast-selling Scorpio model—one-fifth of what it would cost in Detroit. Tata Motors recouped its development costs within a year on the Ace, a small truck that costs about \$2,500.

In chapter 2, authors Carl Dahlman, Mark A. Dutz, and Vinod K. Goel discuss the tremendous potential of India's efforts to expand knowledge and commercialization through formal R&D and to move ideas from laboratories to markets. The world has acknowledged India's R&D potential. More than 300 MNCs have set up R&D and technical centers in India. But despite their recent increases in R&D spending, national corporations and other domestic enterprises are not

systematically exploiting this potential to India's advantage. Indigenous R&D spending as a share of GDP remains low and dominated by the public sector. Furthermore, much of the knowledge that is created—especially by the public sector—is not commercialized. To fully exploit India's R&D potential, the government must take three key steps:

- increase private R&D efforts
- increase the impact of public R&D
- strengthen commercialization of knowledge.

Private R&D could be increased by enhancing support for early-stage technology development (ESTD) programs. During 2006, R&D spending by roughly 300 MNCs in research labs in India appears to have significantly surpassed spending by India's private sector. Although the growth of MNC R&D provides valuable training for Indian scientists and engineers, possible negative externalities in the short term include the diversion of researchers' focus from domestic to MNC issues and increased salaries that may make it difficult for universities and public labs to compete for needed talent. India's large demographic dividend should lead to a sharp supply response over the longer term with appropriate incentives for the development of higher-end skills, with likely enormous longer-term benefits to the Indian economy from greater exposure to MNCs. Two areas need reform:

- *Studying MNC spillovers and adjusting incentives.* A study on the externalities of MNC R&D centers would help indicate how best to adjust existing incentives, including how to ensure that small and medium enterprises (SMEs) can still employ competent technical personnel as the talent gap is being addressed.
- *Consolidating and expanding ESTD programs, and developing pro-innovation public procurement policies.* To support private R&D more effectively, the government should conduct an independent review of ESTD programs with international benchmarking. Based on such a review, programmatic reforms could include establishing a matching grant program building on India's Sponsored Research and Development (SPREAD) and Small Business Innovation Research Initiative (SBIRI) programs, targeted largely at smaller enterprises. The government also should consider developing a national policy and action plan to more effectively use public procurement as an effective policy instrument to promote innovation.

To improve the impact of public R&D, India should consider allocating more resources to productive and social applications. Less than 20 percent of public support for R&D is allocated to civilian applications: 8 percent goes to the 38 labs under the Council of Scientific and Industrial Research (CSIR), 4 percent to Indian Council of Agricultural Research (ICAR) institutions, 4 percent to the applied research programs of the Department of Science and Technology, and 1 percent to the Indian Council of Medical Research (ICMR). India should consider the following:

- *Increasing resources for civilian research.* CSIR was restructured in the 1990s to focus on more market-driven R&D; further restructuring is ongoing. Still, the

public R&D system would benefit from independent evaluation and restructuring across the three main central government research agency networks (CSIR, ICAR, ICMR). Such actions would increase cross-institutional synergies and their focus on commercialization. A systemwide action plan would also consolidate and transfer some R&D labs to the private sector, so that their work becomes fully market driven.

- *Providing more support for university R&D.* Basic science and engineering research of a public goods character can probably be better supported through competitive grants along the lines of the U.S. National Science Foundation, as contemplated in the planned National Science and Engineering Foundation, as well as through greater partnerships and researcher exchanges with international research laboratories.
- *Strengthening support for R&D for high-risk technologies through the New Millennium Indian Technology Leadership Initiative (NMITLI).* Though young, the NMITLI has a number of impressive precommercialization accomplishments. CSIR plans an independent evaluation of the program with international benchmarking. Plans for scaling up the NMITLI include supporting pre- and post-NMITLI activities, opening the program to international collaboration, and giving grants to both research institutions and private enterprises, with success royalties to be shared.

Fostering increased collaboration among R&D institutes, universities, and private firms would help strengthen commercialization of knowledge. The Indian private sector has little interaction with public R&D. Possible areas of reform include the following:

- *Strengthening incentives to commercialize publicly funded R&D.* The U.S. Bayh-Dole Act (1980) encouraged university professors and students to commercialize their intellectual property. India should consider strengthening incentives to commercialize publicly funded R&D by passing legislation inspired by the Bayh-Dole Act but appropriate to the Indian context. India's situation differs from that in the United States in 1980 in that India has no law prohibiting patenting development and commercialization derived from using public research funds. Still, there would be a signaling benefit from clarifying India's legal framework along the lines of the CSIR and Patent Facilitation Center guidelines in force at some ministries. Any new law should promote an entrepreneurial spirit on campuses and at research institutes—including the freedom to negotiate deals with private partners, and rewards for labs and individuals who contribute to revenues.
- *Improving support infrastructure for India's regime for intellectual property rights (IPR).* India's legal framework for IPR has been modernized with the 2005 amendments that brought its patent laws into full compliance with the World Trade Organization (WTO) Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS). However, India should consider addressing outstanding IPR implementation issues. The drive to modernize India's IPR implementation

system is already under way. In addition, the government is expediting plans, among others, to upgrade Indian Patent Offices and expand support for individuals and organizations seeking to patent in India and abroad through an enhanced patent facilitation center. For the longer term, the government is considering creating a special court of appeals for IPR. Finally, to provide country-strategic policy advice on complex IPR-related issues such as technology advances and ensure that they are resolved in India's interest, the government is considering creating a policy-oriented think tank on outstanding intellectual property (IP) issues.

- *Supporting technology transfer offices and a patent management corporation.* Legislation should require government agencies that issue research grants to motivate universities, research institutes, and their individual researchers to seek and exploit patents and engage in technology transfer programs with industrial concerns. A patent management corporation structured as a public-private partnership and as a replacement for or restructuring of the National Research Development Corporation (NRDC) could play a useful role by managing the patent portfolios from CSIR and other public labs and universities, and facilitating their commercial exploitation—as well as provide strategic down-to-earth IP guidance to SMEs.
- *Promoting greater mobility.* Mobility of personnel among public R&D labs, universities, and industry should be encouraged through competitive awards with generous stipends, both within India and within an international context.
- *Expanding technology parks and incubators.* Technology parks and incubators should be expanded with government support and private finance, and management should be based on international best practice. Spin-offs from universities and public research labs should also be encouraged, to create new companies. Scientists should be allowed to start spin-offs while holding their current jobs.
- *Broadening SPREAD.* SPREAD's success as the first formal program to encourage collaboration between Indian technology institutes and firms should be broadened, with a likely focus on SMEs. Its expansion should be based on international benchmarking—including the U.S. Small Business Technology Transfer program, which provides matching grants and requires collaborative commercialization.
- *Creating a Global Research and Industrial Partnership (GRIP) program.* To spur greater international collaboration, the government plans to set up a GRIP program. Inspired by the Israeli-U.S. Binational Research and Development Fund, India's program will support advanced R&D and commercialization carried out jointly by Indian enterprises and those from specific countries, such as Canada, Israel, Russia, and the United States.

Diffusing and Absorbing Knowledge

The Central Leather Research Institute, the largest such institute in the world, implements the Mission for Leather, with the goal of spreading and sustaining a technology culture in India's leather sector. The institute trains workers in all areas, from flayers and

those engaged in collecting raw materials to designers. The global leather industry sources manpower from the supply of trained Indians.

In chapter 3, authors Vinod K. Goel, Carl Dahlman, and Mark A. Dutz discuss how India stands to gain tremendously from increased diffusion and absorption of existing national and global knowledge. Reaping the large, enterprise-based productivity returns from better knowledge diffusion and absorption requires

- spurring flows of global knowledge;
- improving the diffusion and absorption of metrology, standards, testing, and quality (MSTQ) services; and
- strengthening the absorptive capacity of small enterprises.

A range of factors can be strengthened to enable enterprises to absorb knowledge for increased productivity. This book focuses on enhancing global knowledge flows; improving MSTQ services; and strengthening the absorptive capacity of small enterprises. A number of factors help enterprises absorb local and global knowledge. Vigorous competition from local and international rivals is the most important—not only to create and commercialize new knowledge, but also to scour the world for appropriate knowledge, buy it, adapt it for local use, and integrate it in production processes. Other factors include ease of access for acquiring technology (wherever it was developed); sufficient managerial, organizational, and technical capacities within enterprises to use more advanced knowledge; dense links among MSMEs and with dynamic larger enterprises; and sophisticated, demanding local customers. This volume focuses on a few areas with significant scope to build on the progress that has been made in recent years.

By building on its liberalization efforts and further facilitating global knowledge flows, India could help enterprises better absorb knowledge of best practices. India's liberalization of flows of goods and services, capital, technology, and people has had a tremendously positive impact on its economy. The spectacular development of auto components and assembly is perhaps the best illustration of the benefits of a more open business environment. However, India should do more on trade and FDI openness to help its enterprises remain competitive relative to those in comparator countries. Three action areas follow:

- *Increase openness to trade and FDI.* Although India has liberalized many of its trade and FDI policies, implementation remains a problem. Recommendations for increased trade integration include expediting trade liberalization—including the short-run priorities of extending duty drawbacks on imported inputs for exporters, strengthening export promotion for entry into global supply networks, and reducing procedural requirements for both exporting and importing. Recommendations for increased FDI include opening remaining eligible sectors to FDI and setting up a one-stop shop for foreign investors. Longer-term goals should include increasing India's attractiveness to foreign investors by significantly enhancing the efficiency of contract enforcement.

- *Ease technology transfers and set up a technology acquisition fund.* Although India has significantly liberalized its technology transfer regulations in recent years, there is scope to further reduce barriers to technology licensing contracts. The government also may want to consider strengthening support infrastructure for technology licensing by setting up a technology acquisition fund on a public-private partnership basis.
- *Leverage the talents of the diaspora.* Some 2 percent of India's population lives abroad. Their aggregate incomes are roughly equal to two-thirds of India's GDP. India can do a lot more to leverage its large diaspora pool of entrepreneurs and technologists. Initiatives could include supporting a more formal diaspora network, building on existing groups that aggregate diaspora talent and capital for use in India—one that locates individuals to enhance innovation policy and evaluation; enrich the management of scientific institutions and programs; provide teaching, consultancy, and mentoring resources for Indian innovators; and help commercialize Indian intellectual property domestically and abroad.

Improving MSTQ services would help diffuse quality standards and their absorption by enterprises. Standards and quality are closely linked to innovation and productivity. But relative to comparator countries, the absorption of quality in India and the use of its MSTQ system appear low. India's standards and quality system is fairly well developed, but it is dominated by the public sector. A key action area is to *create a world-class, demand-responsive MSTQ infrastructure*. In addition to the need for increased competition as a stimulus for quality upgrading, India should modernize its MSTQ infrastructure, especially metrology, to international standards. Modernization should start with a review of MSTQ programs—examining their governance, management structures, and effectiveness to maximize synergies among initiatives by various ministries and private actors.

Expanding support programs for MSMEs would help increase their absorptive capacity. The skewed distribution of enterprise productivity by sector, with smaller enterprises furthest from top local performers, indicates low absorption of existing knowledge by most enterprises, especially smaller ones. But this skewed distribution also indicates the potentially large productivity and output increases from diffusion and absorption of available national and global knowledge. A key action area is to *strengthen knowledge upgrading initiatives, including technology support at the cluster level and softer organizational capabilities*. Key inputs to enterprises' absorptive capacity are sufficient managerial, organizational, and technical skills. Although the government has a range of policies and programs to promote technology absorption by smaller enterprises, the Ministries of Science and Technology and Small Scale Industries have to do more analysis of how effective they have been. In particular, support for cluster development deserves careful assessment. There is enormous potential for enterprises to absorb knowledge from vertical links with larger, more competitive firms and from horizontal links with enterprises facing similar challenges. The concerned ministries should thoroughly assess existing programs. Based

on this assessment, the government should strengthen and expand effective programs and discontinue or modify ineffective ones.

Promoting Inclusive Innovation

The Honey Bee Network consists of innovators (individuals, farmers, entrepreneurs), policy makers, academics, and nongovernmental organizations (NGOs) committed to recognizing and rewarding innovative ideas and traditional knowledge produced at the grassroots level, using local language interfaces. The network has, in the National Innovation Foundation repository, more than 50,000 innovations and traditional knowledge practices from over 400 districts of India. The related Society for Research and Initiatives for Sustainable Technologies and Institutions has, among other activities, organized biodiversity contests and supported the grassroots development of botanical pesticides and health care products.

The authors of chapter 4, Anuja Utz and Carl Dahlman, suggest that India needs to focus more on promoting inclusive innovation. A three-pronged strategy could make India's innovation system better meet the needs of the economically weaker sections of Indian society:

- Harnessing, increasing, and redirecting formal creation efforts
- Promoting and diffusing innovations by grassroots entrepreneurs
- Helping informal enterprises better absorb existing knowledge.

The main recommendation of this chapter is to create incentives for pro-poor early-stage technology development (ESTD) and commercialization by the formal sector, possibly by providing more preferential matching grants to collaborations among public R&D entities, industry, universities, NGOs, and global poverty alleviation networks. In addition, grassroots innovation networks should be formally evaluated and supported. Finally, government programs should promote knowledge absorption in the productive sector and extend the reach of markets to the common man.

Public policy needs to play a bigger role in increasing India's innovation efforts to address the needs of the poorer segments of the informal sector, in both urban and rural areas. Unless more efforts are made to address the needs of the poor, the growing divergence in productivity between agriculture and knowledge-intensive manufacturing and services will lead to higher income inequality. Innovative activities can play a critical role in reducing the costs of goods and services and in creating sustainable income-earning opportunities for the poor. To bolster inclusive innovations, India would benefit from a crosscutting strategy that harnesses formal creation efforts for the poor; promotes, diffuses, and commercializes grassroots innovations; and helps the informal sector better absorb existing knowledge.

By building on public R&D and university initiatives and encouraging private and global initiatives, India could harness creation and commercialization efforts by

the formal innovation system for poor people. Public research for development and university initiatives have generated benefits in several pro-poor directions. These include the preparation of more than 2,000 groundwater prospect maps, the discovery of a new antituberculosis molecule, and the incubation of n-Logue Internet rural service centers. Private initiatives include the solar power pilot program for poor rural households in Karnataka by the United Nations Environment Program with the Shell Foundation and ultra-low-cost mobile handsets produced by Nokia. Still, formal R&D to meet the needs of the poor has been too low. A key action area is to *provide additional matching grants for pro-poor ESTD followed by commercialization*. More favorable support for pro-poor ESTD could spur a significant increase in collaborative projects among public R&D entities, universities, NGOs, national industry, and global networks. Approaches could include providing more preferential matching grant terms for formal sector activities that alleviate poverty under a consolidated ESTD program.

Deepening grassroots networks and strengthening IPR for traditional knowledge would promote and diffuse grassroots innovation. A number of efforts support grassroots innovation. Nongovernmental initiatives include the Honey Bee Network, which recognizes innovative ideas produced by individuals and communities at the grassroots level, and the Society for Research and Initiatives for Sustainable Technologies and Institutions, which provides financial and institutional backing to the Honey Bee Network. Government initiatives include the Grassroots Innovation Augmentation Network, which functions as an incubator, and the National Innovation Foundation, set up by the Department of Science and Technology to document grassroots innovations. The government also set up a Traditional Knowledge Digital Library to create a database of indigenous knowledge related to medicinal plants. These initiatives have to be independently evaluated for reach and effectiveness. Areas requiring change follow:

- *Deepen financial support for grassroots innovators.* More concessional matching grants for ESTD should be given to grassroots innovators. An example is the harnessing of formal creation efforts for the poor as part of a consolidated and expanded SPREAD/SBIRI program. Once prototypes are developed, they would become candidates for the fund-of-funds window, which considers pro-poor grassroots innovation. Moreover, the National Innovation Foundation should be expanded in ways that enhance and scale up measurable impact.
- *Strengthen IPR for traditional knowledge.* Recommendations to strengthen IPR for traditional knowledge focus, first, on charging the policy-oriented IPR think tank (proposed above) with completing the Traditional Knowledge Digital Library to prevent international patenting of India-based traditional knowledge. Second, the think tank would assess the costs and benefits associated with moving forward with an IPR regime to leverage traditional knowledge into revenue streams.

To help the informal sector absorb knowledge, the government should extend to the informal and rural segments of the economy support programs to strengthen the

absorptive capacity of smaller enterprises. A range of support networks—research institutions, corporations, trader-entrepreneurs, NGOs—try to reach the poor, with unrealized synergies. Those efforts to promote the diffusion and absorption of knowledge in the informal sector appear ineffective, especially given the scale of the challenge. A key action is to *extend technology upgrading programs to informal and rural sectors*. As with support to strengthen the absorptive capacity of smaller formal enterprises, it is essential to undertake a thorough assessment of the reach and effectiveness of existing programs. Based on this assessment, effective programs should be strengthened or new programs introduced to develop a more formal, programmatic approach to this critical but underserved area.

Strengthening Skills and Education for Innovation

The National Association of Software and Service Companies (NASSCOM) has introduced a national assessment of competence for IT and business process outsourcing workers. This test (covering communication, analytical, and keyboard skills) is a market opportunity for private training institutes, spurring them to adapt and increase the market relevance of their courses—helping transform the trainable workforce into an employable workforce.

In chapter 5, authors Isak Froumin, Shanthi Divakaran, Hong Tan, and Yevgeniya Savchenko discuss that India needs to transform its immense young labor pool into a skilled workforce able to take advantage of new and existing knowledge. To fully unleash India's potential as an innovation economy, the government needs to

- improve the delivery of basic skills to both the formal and informal sectors;
- strengthen enterprise-based training and vocational education and training; and
- increase the transfer of market-relevant knowledge-creation skills in higher education, particularly by universities not in the top tier.

India must convert its youth into a skilled workforce. More than 500 million Indians are younger than 25. By 2050 India is expected to overtake China as the world's most populous nation, and over the next five years will be responsible for nearly a quarter of the increase in the world's working-age population. Already, India has almost a third of the available labor supply in low-cost countries.

These figures represent an enormous competitive advantage for India in its emergence as an innovation economy, including as a supplier of skills to the world. However, the widespread perception that it has unlimited employable human resources has changed. India has a growing shortage of skilled workers—caused largely by workforce development and education systems that do not respond adequately to the economy's needs. To fully unleash its potential, India must address three constraints that prevent many of its workers from acquiring the skills needed to contribute to the innovation economy: inadequate delivery of basic skills to both formal and informal sectors; underinvestment in enterprise-based training and inadequate quality of vocational education and training; and insufficient transfer of

market-relevant knowledge creation skills at the higher education level, particularly by universities not in the top tier.

To increase productivity in both the formal and informal sectors, increased efforts are needed to combat illiteracy and provide basic skills. India's high illiteracy limits the population's capacity to acquire the basic skills needed for an innovation economy and curbs the productivity potential of the informal and lower-skill sectors. Reading and writing skills are low even among the literate population. Low worker education contributes to low firm productivity. The country has taken significant steps to reach its high enrollment rate of 94 percent in elementary education, though quality continues to suffer. In contrast, secondary education (grades 9–12) enrollment remains low, at 38 percent. This low secondary education enrollment creates a bottleneck impeding the supply of students for tertiary education. A focus on memorization, use of outdated curricula, and chronic teacher absenteeism have led to an education system that does not prepare students for a market that increasingly rewards problem solving, communication skills, teamwork, and self-learning. Despite a variety of programs to develop skills in the informal sector, the resources directed to the sector are not aligned with its size and the diversity of skills needed. Two actions needed are the following:

- *Use innovative approaches to improve the quality of primary and secondary education.* The government should revamp the primary and secondary education system by modernizing curricula and creating a more flexible, market-responsive education system. New approaches must be experimented with to address existing problems.
- *Strengthen basic skills for the informal sector.* The government should continue to invest in programs that combat illiteracy. It also should facilitate transfer of skills to the informal sector by supporting NGOs that provide training to meet the needs of the informal economy. These skills include training instructors, developing curricula, and encouraging external financing of informal training programs.

Enterprises need stronger incentives to invest in worker training and in vocational education and training that better meet market needs. Indian employers' underinvestment in worker training places India at a competitive disadvantage. A firm's capacity to create or absorb knowledge depends on the skills and training of its workforce. Yet only 16 percent of Indian manufacturing firms provide in-service training, either in-house or external—compared with 92 percent in China. Two recommendations follow:

- *Strengthen enterprise-based training.* The government should help ensure that the benefits of in-service training are widely recognized by enterprises while also providing strong financial incentives—such as matching funds—for firms to invest in such training.
- *Improve vocational training.* India's vocational education and training systems have been unsuccessful in producing graduates able to meet market needs, particularly because of a lack of interaction with industry in curriculum development. Aligning these systems with market needs requires restructuring—including private participation in the management of systems, curriculum development,

and system financing; and stronger performance incentives for vocational education and training institutions.

India's higher education system needs to produce more scientists, engineers, and other Masters and PhD graduates with skills matched to the needs of the innovation economy. Universities are the cradle for sustained creativity and innovation. But India's demand for highly educated, skilled workers outstrips its supply. The high demand is fueled partly by India's popularity as an R&D destination for multinational corporations luring away domestic talent, and partly by the blossoming of India's IT and ITES sectors. To maintain its share of global knowledge services, India will need 2.3 million knowledge professionals by 2010. Instead, it may face a deficit of up to 0.5 million workers. Despite the prestigious standing of several Indian institutions of higher learning, the education system's output remains uneven. Quality training continues to concentrate on islands of excellence: 80 percent of doctorates in engineering are awarded by 20 leading institutions, and 65 percent of doctorates in sciences come from 30 institutions. India produces fewer than 7,000 PhDs a year in the faculties of science, engineering, and technology.

The lack of skilled researchers and knowledge creators is manifested in low output of high-quality scientific research. Furthermore, weak links with industry have created a mismatch between the needs of the market and the skills of the highly educated workforce. Only 10–25 percent of general college graduates are suitable for employment. In addition, India has a small number of high-quality management programs, and even they are inadequate to support the growing need for management and supervisory skills in both knowledge-intensive and lower-skills sectors. Two key action areas follow:

- *Increase private participation in higher education.* To address the growing supply constraint of high-quality education institutions, India requires stronger incentives to attract domestic and foreign private participation in higher education and its financing. The November 2006 agreement by the government to allow FDI in higher education and foreign universities to set up campuses in India is a positive step in this direction.
- *Raise fiscal and managerial autonomy of universities and colleges.* A drastic increase in joint training programs with industry would help ensure that university curricula reflect market needs. Competitive grants for academic innovations and performance-based incentives for professors would also foster a more dynamic academic environment—one better aligned with India's growth in knowledge-intensive sectors.

Upgrading the Information Infrastructure

After mobile phones were made available to fishermen in Kerala, they were able to call several markets and agree on selling prices before landing their fish. Within a few weeks the dispersion in fish prices fell and there was no more wastage. The profits of fishermen

increased 9 percent while the average price of fish fell 4 percent—to the delight of customers.

In chapter 6, authors Shanthi Divakaran, Anil Srivastava, and Mark Williams conclude that India needs to improve the ease and cost of accessing and sharing information and knowledge among enterprises, knowledge workers, and researchers. Upgrading the information infrastructure for innovation requires

- making information and communication technology (ICT) more available to both rural and urban users, and
- strengthening India's National Research and Education Network (NREN) infrastructure for high-end research institutions.

The creation of new ideas and dissemination of ideas between firms and countries are strongly influenced by the availability of information, cost of obtaining it, and ease with which it is passed on. Electronic communications systems lie at the heart of this information transfer process. Investment in ICT services is one way to stimulate growth in national innovation and productivity. India's ICT sector has grown rapidly over the past 20 years. The IT industry, for instance, is becoming an increasingly important part of the economy. High investment in ICT services, increased competition, and low equipment prices have raised teledensity and driven down prices—to the point that Indian consumers now enjoy some of the world's lowest charges for telephones. At year-end 2006, India had roughly 41 million wireline subscribers, 150 million wireless subscribers, and over 1.8 million broadband subscribers. Rapid growth in penetration rates has reduced the price of information for individuals and businesses. However, this growth must continue and reach all segments of the economy to fully support the development of an innovation economy. To do so, the government must address a number of policy issues.

India has made rapid progress in improving access to telecommunications services, but urban teledensity still lags behind international comparators, and rural access remains insufficient. Households and small enterprises worldwide use basic ICT services to better organize their economic activities and marketing. China's penetration of broadband access is 30 times greater than India's. Teledensity in India in urban areas is 40 percent, compared with 2 percent in rural areas. Only 30 percent of India's population is covered by a mobile signal, versus more than 90 percent in China and South Africa. The value of ICT infrastructure to Indians and the lack of alternatives in rural areas are shown by the speed at which phone services are taken up when made available. Using ICT can spur institutional innovations to improve public service delivery in sectors such as health, education, energy, and transport. Two recommended actions, both benefiting from increased competition, follow:

- *Expand infrastructure for rural access.* By freeing more radio spectrum and making it available to operators of voice and data services, the government can reduce rollout costs and operators can accelerate the provision of services—including

broadband wireless services in rural areas. The government should also provide targeted subsidies for rural mobile and broadband rollout in a way that rewards efficiency, maximizes private investment, and does not distort competition.

- *Deepen infrastructure for urban access, especially broadband services.* India's success in expanding the supply of narrowband (that is, voice) communications infrastructure must be replicated for high-speed data services. Increased access to broadband networks will involve faster allocation of spectrum for wireless broadband rollout and revision of the policy definition of broadband to speeds higher than 256 kilobits per second.

A high-speed national research and education network would enable Indian scientists and researchers to work with the global scientific community and remain at the global frontier of science. Although there is widening awareness that network-enabled collaboration accelerates the pace of new discoveries and the expansion of knowledge, India is significantly behind global comparators in high-speed networking for research and academic institutions. NRENs have become an essential part of national R&D infrastructure. More than 70 countries connect researchers and scientists through high-speed networks, with the emerging standard for connectivity at 10 gigabits per second.

In contrast, most Indian scientists and researchers are not connected to high-speed networks. NRENs' main impact on an innovation economy is their potential for more productive research through formal, high-speed mechanisms that create and absorb knowledge by tapping into global networks. The case for NRENs also includes improved broader access to information, increased opportunities for collaboration, expansion of distance education at lower cost, and opportunities to participate in innovative research on the future of NRENs. Investment in shared cyber infrastructure by the U.S. National Science Foundation and similar institutions in Europe reflects the growing importance of NRENs. The main responsibilities of a typically nonprofit NREN entity are to mobilize and aggregate demand, manage underlying infrastructure, and deliver services—including connections to global high-speed networks at agreed standards. No single entity in India is entrusted with these responsibilities; the result is parallel high-speed networking efforts with duplicated resources. Indian policy makers recognize the importance of advanced networks for the knowledge economy. They should explore the cost of NREN infrastructure and the appropriate organizational structure to deploy and manage the network. A key action is to *upgrade India's NREN*. India should quickly agree on the appropriate NREN entity structure to manage the network, aggregating available infrastructure and building on it as needed. Programmatic rollout would include a prototype phase to test the selected management model and partnership arrangements, a decision on the right own or lease model for wider outreach, and phasing of connectivity to user research and education institutions. Demand could be ensured by subsidizing academic institutions for their required local network investments and ensuring that institutional incentives foster collaboration and network activity.

Enhancing Innovation Finance

The Acumen Fund, a nonprofit venture capital fund, takes a market approach to combat poverty, focusing on both opening markets and making goods and services more accessible to the poor. Acumen has taken a \$1 million equity stake in and loaned \$600,000 to Drishtee.com—an e-kiosk that gives rural poor people access to Internet services—to help build more kiosks and add new services, including online health care. However, the fund pulled out of a fluoride filtration company when the entrepreneur changed strategy and started pursuing subsidized government contracts.

Chapter 7, by Inderbir Singh Dhingra, discusses how India can meet the final challenge—enhancing public finance for innovation, which is essential to enabling more state-of-the-art innovation, increasing the use of existing knowledge by enterprises, and promoting inclusive innovation. Areas of support include

- providing financing for ESTD;
- deepening early-stage venture capital; and
- strengthening finance for technology absorption by MSMEs.

Among these, addressing the ESTD funding gap is the top priority because the early-stage venture capital gap will probably narrow over time through market forces, while the ESTD funding gap will not.

The government should expand financial support for ESTD. This requires multi-pronged reforms to improve the enabling environment for innovation. These should include increasing the scale and scope of public support for private R&D and strengthening incentives for research and commercialization through more incubators, technology parks, and spin-offs. Any interventions supporting venture capital need to be preceded or complemented by interventions that address the ESTD funding gap.

To deepen early-stage venture capital, India should consider both supply- and demand-side reforms. On the demand side, besides increasing ESTD, more efforts need to be undertaken to increase techno-entrepreneurship. Entrepreneurship training should be incorporated more systematically into engineering training. Greater incentives should be provided to young scientists, engineers, MBAs, and other professionals to launch technology-based companies. On the supply side, despite a significant number of major venture capital funds being created in India in the past 12–18 months, biases remain toward larger funds, the IT sector, and more proven business models. New efforts in seed and angel funding trying to fill the gap are insufficient. Taking into account the amount of funding available at the post-early-stage phase, the total funding available at the seed and early stage, especially under \$2 million, is a serious bottleneck. This lack of funding is even more of a constraint because early-stage financiers provide not only capital but also management support, advice, reputation, and other forms of mentoring critical to

successful commercialization. Two reforms would increase the supply of early-stage venture capital:

- *Introduce facilitating regulations.* Measures should make it more attractive for wealthy individuals to invest in venture capital funds. This can be done through tax incentives and changes in the Securities and Exchange Board of India rules to allow tax pass-through benefits for “accredited” angel investors. The investment guidelines of pension and insurance funds could also be relaxed to increase their investments in early-stage ventures.
- *Create a fund of funds.* Also crucial is the creation of a fund of funds, where the government would provide leveraged returns to private investors by increasing potential returns or reducing potential risks. The fund could cover innovations in areas overlooked by the market, including agro-industry, rural industry, pro-poor grassroots industries, and start-ups where companies need to advance an innovation. The fund should have two distinct windows: one focused on pro-growth innovations, the other on inclusive innovations. Governance of the fund-of-funds is perhaps the most critical factor for success, so that selection of fund managers and program control are professional, free from bureaucratic burdens, and independent of political interference. The individual venture capital funds should be managed by the private sector.

Finally, the government should implement measures to improve access to finance for innovative MSMEs upgrading their technology. Although no official data exist on the magnitude of the finance gap facing MSMEs wishing to absorb technology, the general constraints that they face in financing investments suggest that it is significant. There is evidence that access to funding for absorption of innovative practices is a more serious problem in India than in most other developing countries in Asia and Latin America, and more constrained for smaller enterprises and those operating in traditional industries. India should *strengthen finance for technology absorption by MSMEs*. Possible measures for government action include improving credit information on MSMEs to reduce transaction costs—thereby lowering lending rates, addressing the problem of collateral and reducing default risk by lenders, and establishing a policy and regulatory framework to foster the development of leasing finance as an instrument to finance small, innovative enterprises.

The Indian Context and Enabling Environment

Mark A. Dutz and Carl Dahlman

This book focuses on how to foster increased innovative activities in India to meet the twin challenges of sustained growth and pro-poor development. India is an extreme “dual” economy.¹ At one extreme, it is the world’s fourth-largest economy in purchasing power parity (PPP) terms, it is a nuclear and space power, and it is increasingly becoming a top global innovation player in certain key economic sectors—such as biotechnology, pharmaceuticals, automotive components, information technology (IT), software, and IT-enabled services (ITES).

At the opposite extreme, India largely remains a subsistence economy. With an average per capita income of \$720 in 2005, India is still a low-income and mainly rural, agrarian economy. About a quarter of its population lives below the national poverty line, with significant spatial variance across and within states.² Roughly 70 percent of its population is rural, and 60 percent of the workforce is engaged in agriculture. Illiteracy rates are 46 percent for women and 25 percent for men.³ Given this dual economy, it is natural to ask what can be done both to strengthen the likelihood of sustained high growth rates and to address the unmet needs of the informal sector and the poor. To sustain growth and reduce poverty, India must leverage and improve its innovation potential.

Innovation can be a critical driver of increased productivity and competitiveness and, ultimately, poverty alleviation.⁴ India’s recent acceleration in growth has been impressive. Over the 2004–06 period, real GDP has grown by over 8 percent a year. Growth has been driven by a jump in export-oriented, skill-intensive manufacturing (pharmaceuticals, petrochemicals, auto parts and assembly) and services (IT, business services, finance). These have been accompanied by a jump in innovative activities. Higher productivity and economic growth have raised living standards and reduced the number of poor people.⁵ However, tremendous dispersion in productivity levels remains, both within and across economic sectors. Most workers

in the informal sector—which accounts for roughly 90 percent of the workforce—are underemployed in low-skill, low-productivity, low-income activities.

India's dual economic structure and wide dispersion in productivity levels call for a broader interpretation of innovation. Innovation is defined to include both “new to the world” creation and commercialization activities and “new to the market” diffusion and absorption activities—the first use of existing knowledge in new market contexts to help underperforming enterprises come closer to the global frontier of knowledge. Innovative activities include products, processes, and business and organizational models new to the local environment.

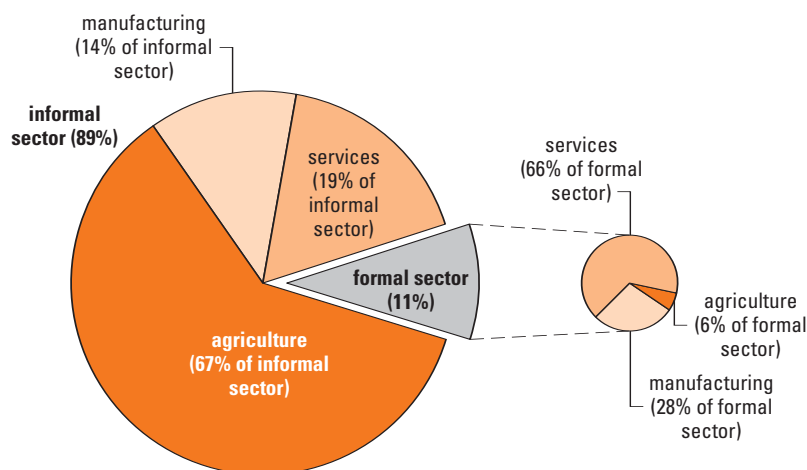
India has even more to gain from economywide productivity increases from diffusion and absorption of existing knowledge than from creation and commercialization of new knowledge. The global technological frontier is moving quickly, simultaneously opening opportunities and posing threats. India needs to tap into this rapidly moving frontier while expanding its comparative advantages. India can and must do more to take advantage of its critical capabilities to enable creation of new global knowledge. Just as important, if not more so, India must develop policies, institutions, and capabilities to diffuse local and foreign knowledge more effectively throughout its economy. From an economic viewpoint, India stands to gain more from catching up to the world frontier than from pushing out the frontier. Thus, the challenge of innovation in India combines a drive to move the global technological frontier, an effort to increase the speed at which global innovations enter the country, and the most pressing need—to improve prevailing practices across the entire economy.

Structural Features of the Indian Economy

The use of knowledge for productive economic purposes varies as countries develop. Knowledge needs are related to a country's economic structure, and this structure changes as a country develops. In developing countries, such as India, agriculture is the economic sector absorbing the most labor. As countries increase agricultural productivity through new technologies, the workers released by agriculture are absorbed by the industrial sector—particularly manufacturing. In addition, the service sectors expand. Initially, commerce and construction expand supported by low skills. But eventually, these and other service sectors, such as tourism and health services, develop and become more knowledge intensive.

Economic Dualism

India's economic dualism is stark, with less than 3 percent of the workforce employed in the formal private sector and the bulk of the workforce in the informal sector. Formal versus informal employment is a very imperfect proxy for India's dual economic structure.⁶ According to available data, the formal sector accounts for just 11 percent of a workforce of roughly 460 million; 89 percent of workers are

Figure 1.1 India's Dualistic Economic Structure

Source: World Bank 2006f.

in the informal sector.⁷ In agriculture only 1 percent of employment is formal, and even in manufacturing the share is just 19 percent. By far, most formal employment (66 percent) is in the tertiary or services sector, in which government accounts for the majority. Roughly 50 percent of workers are self-employed. The bulk of self-employment is in low-productivity subsistence agriculture and services. Figure 1.1 summarizes this dualistic structure of the Indian economy.

India needs to absorb workers out of agriculture, into manufacturing and services. The bulk of the Indian workforce is engaged in agriculture. Although the share of workers in agriculture has been declining, the decline has not been as rapid as might have been expected relative to other developing countries. By 1999–2000, roughly 60 percent of the overall workforce remained in agriculture. Part of the problem has been that manufacturing employment has not increased much as a share of total employment. As a result, most people leaving agriculture have gone into construction and the service sector—especially trade, hotels, and restaurants; personal, business, and community services; and transport, storage, and communications. The rest of this book does not focus on agriculture because the innovation challenges facing the sector are covered in detail elsewhere.⁸ This volume also focuses largely on central government support programs for industrial innovation—not state programs, which focus more on setting up enterprises.

Productivity Dispersion

Productivity has increased in manufacturing and services, but at very different rates. The productivity of all sectors relative to agriculture (other than construction) has increased significantly over the past 20 years (table 1.1). Most notable have been the

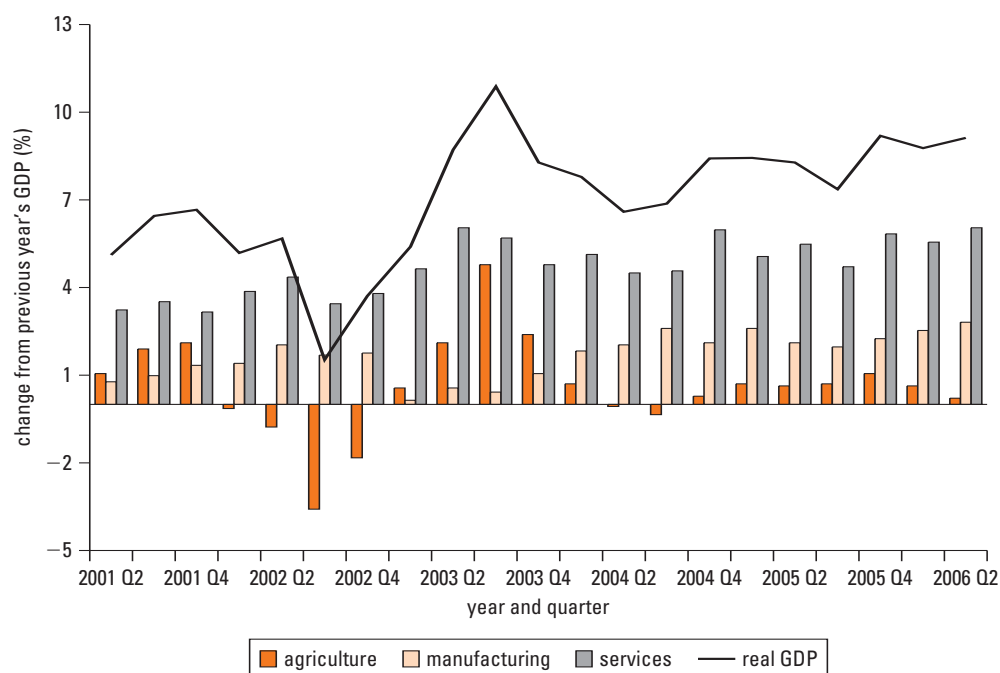
Table 1.1 Changes in Labor Productivity Relative to Agriculture, by Economic Sector Based on Principal Status of Workers, 1983–2000

Sector	1983	1988	1995	2000
Agriculture and allied activities	100	100	100	100
Mining and quarrying	615	641	628	971
Manufacturing	243	272	293	352
Electricity, gas, and water	912	1,101	1,186	1,797
Construction	367	253	294	258
Trade, hotels, and restaurants	312	319	311	321
Transport, storage, and communications	376	424	411	453
Financial, insurance, and real estate businesses	1,673	1,825	2,211	2,276
Personal, business, and community services	221	261	231	358
Prime-age workforce (thousands)	171,029	184,626	259,820	303,895

Source: World Bank 2006f.

relative near doubling of worker productivity in electricity, gas, and water (mostly government monopolies); the almost two-thirds increase in personal, business, and community services (no doubt driven by the business services); the 45 percent increase in manufacturing; and the more than one-third increase in the highly productive finance, insurance, and real estate businesses. The average productivity of this last group is nearly 23 times that of agriculture. However, it accounts for only 1.3 percent of total employment, whereas agriculture accounts for 60 percent. It is discomfiting that the relative productivity of construction—the sector that usually absorbs agricultural labor—has actually fallen; and that of trade, hotels, and restaurants—another high-absorption sector—has hardly increased. In sum, there are widening gaps between the productivity of the enormous agricultural sector and that of more knowledge-intensive sectors.

Strong growth in selected service sectors, complemented by recent growth in manufacturing, suggests strong productivity increases in some sectors—though overall productivity growth remains relatively low. In the period 1993–2004, India's GDP grew by an average of 4.6 percent per year, increasing to an average of over 8 percent for 2004–06 (figure 1.2). Although India's total factor productivity (TFP) growth increased from 0.2 percent a year in the 1960s and 1970s to 2.3 percent in 1993–2004, this still compares unfavorably with China's annual rate of 4 percent. A breakdown across broad sectors reveals India's weakness in manufacturing relative to services: since 1993, while TFP growth in services has been 3.9 percent a year in India (relative to 0.9 percent in China), TFP growth in manufacturing has been only 1.1 percent in India (relative to 6.2 percent in China).⁹ Although TFP growth in India has probably picked up with the increase in GDP growth since 2004 (the figures are not yet available), a key question is the extent to which recent growth is sustainable.

Figure 1.2 Contributions to Real GDP Growth, by Industrial Category, 2001–06

Source: Central Statistical Organization, Government of India.

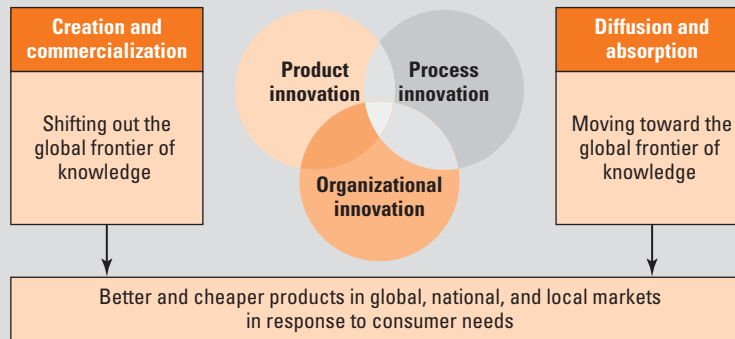
Broadly Based Innovation and Productivity

Innovation is broadly defined to include both creation and commercialization of state-of-the-art knowledge as well as diffusion and absorption of existing knowledge. Available measures of formal innovation inputs—both creation (R&D spending) and absorption (technology acquisition)—are closely and jointly associated with innovation outputs (developing new product lines). Informal efforts to create and absorb knowledge are also associated with innovation outputs. In turn, innovation outputs are strongly associated with enterprise productivity. Important in this context, absorbing existing technology has a stronger association with productivity than does spending on R&D.

Definition and Indicators

Innovation is often defined as the invention and commercialization of new products. This book defines innovation more broadly, to include both “new to the world” creation and commercialization of knowledge activities and “new to the relevant market” diffusion and absorption of knowledge activities (box 1.1).

Creation of new knowledge and its commercialization require research and experimentation as well as incentives, skills, and institutional support to bring the knowledge to market. While knowledge creation traditionally focuses on formal research

Box 1.1 Broadly Based Innovation Activities**Creation and commercialization**

Creation is inventive activity, often the result of formal research and development (R&D) conducted by scientists and engineers. The key institutions involved in formal knowledge creation are public R&D laboratories, universities, private R&D centers, and enterprises. But not all knowledge creation is the result of formal R&D. It is often market- or application-based, driven by an understanding by the innovator of what consumers want. Sometimes the invention comes from experiences with production or from informal trial and error. Sometimes it comes from serendipitous insight. Its origin raises a measurement problem because not all R&D results in inventions, and not all inventions come from formal R&D.

Typically, two phases follow the transformation of a basic idea into an initial proposal format: proof of concept or initial prototyping, and pilot demonstration. For some products (such as software), a first or “alpha” prototype is developed at a business customer location that agrees to be an alpha site because of the perceived value in being involved in testing rather than waiting to buy the product on the market. During this phase, the technical merit and commercial feasibility of the new idea or technology are explored. It is often at this phase that early-stage technology development (ESTD) grants and incubators are most helpful. Although there is no consensus definition of ESTD, it can be broadly defined as the stage at which “the technology is reduced to industrial practice, when a production process is defined from which costs can be estimated, and a market appropriate to the demonstrated performance specifications is identified and quantified” (Auerswald and Branscomb 2003). With proof of concept in hand, pilots are demonstrated and tested, with the development of second or “beta” versions of the prototype for early adopters to work out bugs and evaluate the idea’s commercialization potential. It is often at this second, or pilot, phase that seed and early-stage venture capital may start to become interested.

Commercialization is the process of bringing new inventions to market—that is, the market-based scaling up of production from pilot to mass market that transforms new knowledge to wealth. Products are typically monetized either by licensing or selling the intellectual property or by marketing and selling the product.

(continued)

Box 1.1 continued

The move from basic and applied research to prototype development and pilot demonstration, followed by monetization, is typically complex and nonlinear, with overlaps and feedback between phases and different innovation pathways (Dosi and others 1988). It is not uncommon for unanticipated applications to arise during the process. An important implication of the varied pathways and unpredictability of creation efforts is the desirability of fostering increased collaboration by bringing different players together.

Diffusion and absorption

The main means of diffusion of knowledge or technology transfer are trade (technology embodied in capital goods, components, or products imported or purchased locally, as well as through interaction with foreign sellers and buyers), foreign direct investment, licensing, technical assistance, expansion of enterprises that have developed specific knowledge, copying and reverse engineering, foreign study, technical information in printed or electronic form (including what can be accessed on the Internet), twinning, and training arrangements. Proprietary technology is usually sold or transferred on a contractual basis. Nevertheless, even proprietary technology may leak out depending on the strength of the regime for intellectual property rights and its enforcement, and the capability of users. But a lot of relevant technology is in the public domain or owned by governments that could put it in the public domain. There also are specialized entities, such as productivity organizations and consulting firms, that focus on helping to disseminate technologies. These efforts usually involve training, demonstration projects, or technical assistance on how to use the technology.

Industrial technologies often must be adapted to local conditions—including local raw materials, special characteristics, or to other idiosyncrasies such as local standards, climate, or power sources. It is important to have appropriate mechanisms to educate potential users in the benefits of the technology. Education often involves more than providing technical information. Moreover, use of new technologies usually requires literacy and specialized training. Finally, beyond the specific skills, using new technology often requires access to complementary inputs and supporting industries, and access to finance to purchase new equipment or inputs—or even to buy the technology license.

Source: Authors.

and development (R&D), it importantly includes other market-based and application-based experimentation efforts based on an understanding of what consumers (enterprises, individuals, or groups) want. Creation and commercialization activities can and do take place in both formal and informal (including rural) settings.

Diffusion and absorption of knowledge activities comprise the dissemination, acquisition, adaptation, and use of existing knowledge by enterprises and institutions. For absorption of knowledge by an enterprise to be considered innovative, the technology transfer should be the first use in the enterprise's relevant market. For example, the first leather producer in a village to import and use an international

best practice machine and adapt it to local needs would constitute innovative absorption, while the fifth producer in the village to acquire and use the same machine would no longer be engaging in an innovative act. Innovative activities are not restricted to new products (goods and services of all types)—they also include innovations in processes (production on the shop floor, design, marketing and distribution, financing) as well as innovations in business and organizational models.

Indicators of India's capacity for innovation highlight its promising innovation potential. Most studies on innovation focus on the inputs and immediate outputs of formal R&D, because there is generally more such data on these efforts. Evidence on where India stands comes from quantitative data on formal R&D—such as the stock of scientists and engineers engaged in R&D and R&D spending on the input side, and scientific and technical publications and patents on the output side.¹⁰ The positive perception of India's innovation potential by the international business press provides a useful context for the more quantitative assessment that follows.¹¹ For example, in 2006 the Massachusetts Institute of Technology *Technology Review* (MIT 2006) ranked six Indian-Americans among the top global innovators under the age of 35. Based on respondents from Asia and the Pacific, the Indian company Infosys is among the world's 10 most innovative companies, with only the Republic of Korea's Samsung also included among comparator countries—Brazil, the Russian Federation, China, Korea, and Mexico.¹²

Underpinning India's innovation potential on the input side, its stock of scientists and engineers engaged in R&D is among the largest in the world. India's historically sizable investments in higher education focused on science and engineering. Its concentrated stock of high-caliber human capital is a top reason it is potentially very good at innovation, though this historic competitive advantage is being eroded through insufficient recent and current investment in education and skills.¹³ Estimates of India's number of scientists and engineers that are researchers in R&D vary widely. One estimate is 117,528, compared with 810,525 for China and 487,477 for Russia (table 1.2). But another estimate puts India's number of scientists and engineers at 300,000.¹⁴ Of these, about a third are conducting R&D, a third are performing auxiliary services, and a third are providing administrative and support services (Bhojwani 2006: 9). India has more than 12 million science and engineering graduates—of which 2 million are postgraduates and 100,000 are PhDs (NCAER 2005). Though there is no doubt that India has an impressive stock of skilled talent based on past investments in higher education, the more pressing question is the availability of qualified talent, measured by both quantity and quality (see chapter 5).

Another critical innovation input is aggregate domestic R&D spending, which in India has never exceeded 1 percent of GDP. Over the past 20 years, India's domestic R&D expenditures as a share of GDP have fluctuated between 0.71 and 0.91 percent, with the highest share recorded in 1987 (fiscal year 1987–88). In 2004, the last year with comparable data for India and its comparator countries, India's share stood at 0.85 percent (Department of Science and Technology 2006: 3). These numbers compare unfavorably with comparator countries except Mexico—and then partly because Mexico is relatively integrated with the R&D system in the United States,

Table 1.2 Formal Innovation Inputs and Outputs in Various Countries, 2003–04

Indicator	Brazil	Russian Fed.	India	China	Korea, Rep. of	Mexico
Researchers in R&D, 2003	59,838	477,647	117,528	926,252	151,254	26,800
R&D researchers per million population, 2004	344	3,319	119	708	3,187	268
Spending on R&D (\$ billions), 2004	5.9	6.8	5.9	27.8	17.9	2.7
Spending on R&D (percentage of GDP), 2004	0.98	1.17	0.85	1.44	2.65	0.43
Scientific and technical journal articles, 2003	8,684	15,782	12,774	29,186	13,746	3,747
R&D spending (\$ thousands) per scientific and technical article ^a	682	431	460	953	1,332	722
Scientific and technical journal articles per million population, 2003	47.9	109.1	12.0	22.7	287.5	37.1
Patents granted by U.S. Patent Office, 2004	161	173	376	597	4,671	102
R&D spending (\$ millions) per patent granted ^a	376.7	39.3	15.6	46.6	3.8	26.9
Patent applications granted by U.S. Patent Office per million population, 2004	0.90	1.21	0.35	0.46	97.03	0.98

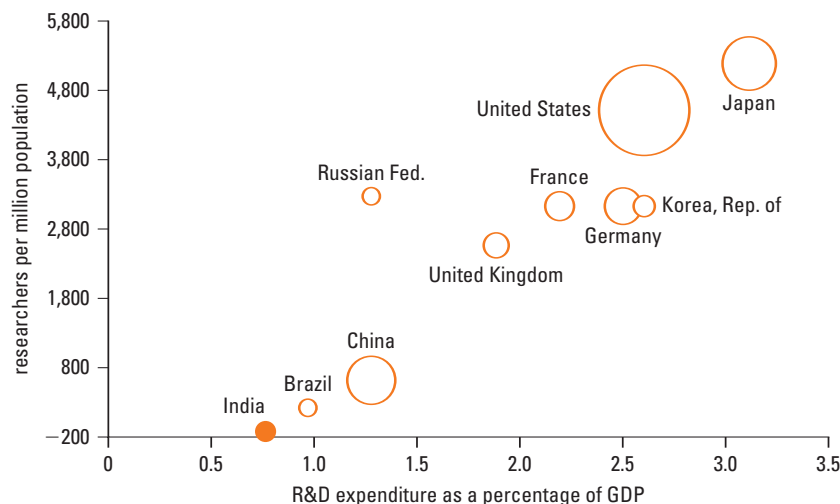
Source: Compiled from data in World Bank (2006g, 2006h).

a. Calculated by dividing estimated R&D spending in 2004 by number of articles or patents.

with more of its R&D occurring there. China's share in 2004 was 1.4 percent and is expected to reach 2.0 percent by 2010, despite rapid growth in GDP. The average for developed countries is roughly 2.5 percent. India's 10th five-year plan, launched in 2002, indicated that R&D spending was to reach 2.0 percent of GDP by 2007. However, given current levels, that goal is unrealistic.¹⁵

Although at nominal exchange rates, India's domestic R&D spending was just \$5.4 billion in 2004, in PPP terms it was \$26.9 billion. The conversion of R&D spending to PPP terms made India the world's ninth largest spender on R&D in 2004 (figure 1.3). This rank reflects the lower local costs of India's R&D spending relative to those of Organisation for Economic Co-operation and Development (OECD) countries.¹⁶ But in PPP terms, China was the third-largest global spender at \$94 billion, just after Japan. Given China's ambitious expansion of investments in R&D and its higher GDP growth, by the end of 2006, China was already the world's second-largest R&D spender in PPP terms, at just over \$136 billion, after the United States at almost \$340 billion (OECD 2006).¹⁷

Domestic R&D spending is dominated by the public sector. India is still at a typical early innovation stage with regard to the distribution of domestic R&D efforts: about 75–80 percent of domestic R&D is conducted by the public sector, 20–25 percent by private enterprises, and just 3 percent by universities. In contrast, average R&D expenditures in OECD countries are 69 percent by enterprises, 18 percent by

Figure 1.3 R&D Effort in Various Countries, 2004*(total gross domestic expenditure on R&D in purchasing power parity dollars)*

Source: Calculated from R&D as percentage of GDP and GDP in purchasing power parity (PPP) terms, data from World Bank (2006h).

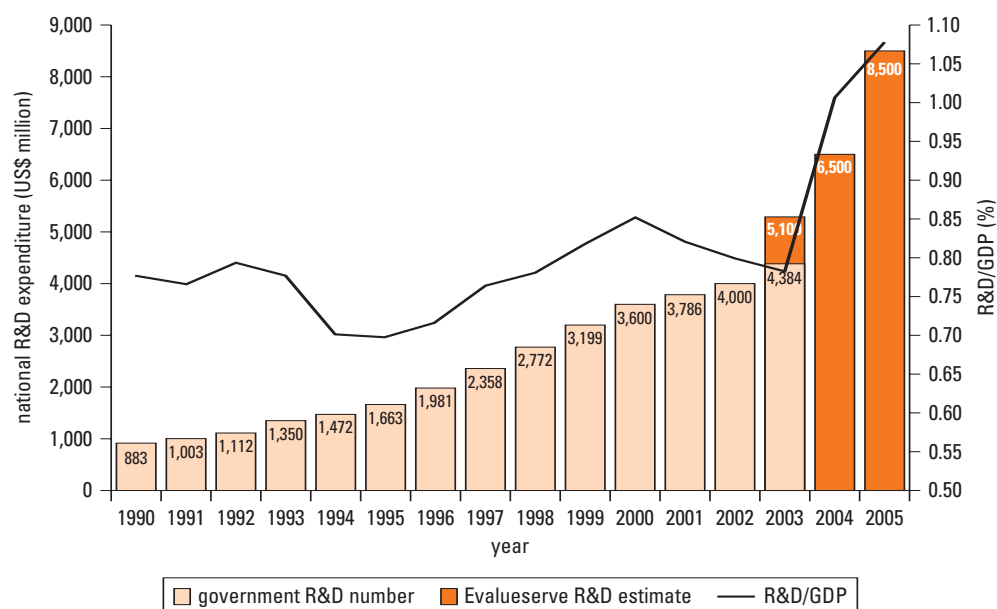
Note: The size of the bubbles represents the gross amount spent on R&D in 2004 in PPP terms.

universities, 10 percent by government R&D labs, and 3 percent by private non-profit institutions (OECD 2005). In China, more than 65 percent of expenditures are undertaken by enterprises. However, with the significant increase in R&D by multinational corporations (MNCs) in India since 2002, total private R&D investment is estimated to have risen from \$0.8 billion in 2002 to \$4.1 billion in 2005. This led to a corresponding increase in total R&D spending from \$4 billion in 2002 (where total private spending was only 20 percent) to \$8.5 billion in 2005 (where total private spending, including MNCs, is estimated to have risen to 48 percent) (figure 1.4).¹⁸

On innovation output indicators, India has a strong record in producing basic knowledge, as proxied by internationally refereed scientific and technical publications. In 2003, the number of Indian scientific and technical articles published in internationally recognized journals tracked by the U.S. National Science Foundation was 12,774, compared with 8,684 from Brazil, 13,746 from Korea, and 3,747 from Mexico. But India is lagging China (27,816) and Russia (15,782) (see table 1.3). The largest share of India's scientific publishing is done by the Council of Scientific and Industrial Research (CSIR), followed by the seven Indian Institutes of Technology and the Atomic Energy Research Institute. The number and frequency of citations of Indian institutes' work in other publications are rising, indicating improved output and quality.

There has also been a significant increase in patent applications filed in India. The largest one-year jump occurred when India joined the World Trade Organization and committed to harmonizing its system with international standards. Between 1975 and 1995, patent applications in India totaled roughly 1,000 Indian filings and 2,000–2,500

Figure 1.4 R&D Expenditure in India, 1990–2005



Source: Department of Science and Technology 2006; Evalueserve 2006.

Table 1.3 Indian Patent Applications and Grants, 1975–2005

Fiscal year	Applications				Patents granted		
	Indian	Foreign	PCT	Total	Total	Indian	Foreign
1975 to 1984 (annual average)	1,119	1,918	n.a.	3,037	1,758	459	1,299
1985 to 1994 (annual average)	1,164	2,608	n.a.	3,772	1,939	498	1,441
1995	1,606	5,430	n.a.	7,036	1,533	415	1,118
1996	1,661	6,901	n.a.	8,562	907	293	614
1997	1,926	8,229	n.a.	10,155	1,844	619	1,225
1998	2,247	6,707	n.a.	8,954	1,800	645	1,155
1999	2,206	2,601	269	5,076	1,881	557	1,324
2000	2,179	2,160	4,164	8,503	1,318	399	919
2001	2,371	1,870	6,351	10,592	1,591	654	937
2002	2,693	1,723	7,049	11,465	1,379	494	885
2003	3,218	1,678	7,717	12,613	2,469	945	1,524
2004	3,630	3,165	10,671	17,466	1,911	764	1,147

Source: Gupta 2006: 39.

Note: PCT = Patent Cooperation Treaty, which India did not join until 1999. n.a = Not applicable.

foreign filings a year (table 1.3). Applications increased significantly when India joined the World Trade Organization in 1995, rising to more than 1,600 Indian and 5,400 foreign filings a year. In 1999, India joined the Patent Cooperation Treaty (PCT), an international organization that eases the filing of patents. After that, many applicants—overwhelmingly but not exclusively foreigners—began using this route.

As India revised its patent laws through amendments to the Patent Act in 1999, 2002, 2003, and 2005, applications by both Indians and foreigners increased even more significantly. By fiscal year 2004–05, there were more than 3,600 Indian applications, more than 3,100 foreign applications, and more than 10,000 PCT filings directed at India (see table 1.3).¹⁹ Statistics on patents granted are harder to determine because different applications move through the application process at different speeds. Patent examinations take arbitrarily long and can entail multiple rounds of correspondence, depending on the application. As a result, patents granted in any given year necessarily result from applications first submitted in earlier years, and so lag behind changes in intellectual property rules and in the national culture, and broader changes in the innovation system.

The share of Indian patent applications in the United States is small but has risen significantly in recent years—led by MNCs and CSIR. The share of Indian patent applications in the United States rose from 0.04 percent of the worldwide total in 1995 to 0.37 percent in 2004.²⁰ A ranking of patents granted in the United States between 1995 and 2004 showed India in 24th place worldwide. Most of the top countries were OECD members. But seven non-OECD economies placed ahead of India: Taiwan (China), Korea, Israel, Singapore, Hong Kong (China), China, and Russia, in that order. The last two may have been expected, China because of its size and Russia because of its technological legacy. It is telling, however, that the five other economies are quite small. Israel is also a special case, but the high rankings of Taiwan, Korea, Singapore, and Hong Kong indicate the importance that these small economies place on competing in the global market based on innovation.

It is also telling to examine who applied for patents in India over 1995–2005. Of the top 50 applicants, 44 were foreign firms operating in India—only 6 were Indian organizations. Three of these were public institutions (CSIR, Indian Institute of Technology, Ministry of Defense), and one was a public corporation (Steel Authority of India). Only two were private Indian firms (Ranbaxy and Dr. Reddy's Lab), both in the generic drug industry that got its start under India's former, more nationalist, patent regime.

Overall, India appears better at producing basic knowledge than commercializable knowledge. Even so, R&D spending appears more efficient in India than in comparator countries. Using the publication of scientific and technical journal articles as a proxy for basic knowledge outputs and patents granted in the United States as a proxy for commercializable outputs, India is relatively stronger in the production of basic than market-driven knowledge. However, based on efficiency of R&D spending, as measured by the relative costs of a scientific and technical publication or a U.S. patent, India does better than all its comparator countries except Russia for journals and Korea for patents (see table 1.3).²¹ India has perhaps the

lowest R&D costs among these countries as a result of its lower pay to scientists and engineers—the main cost component in R&D spending.

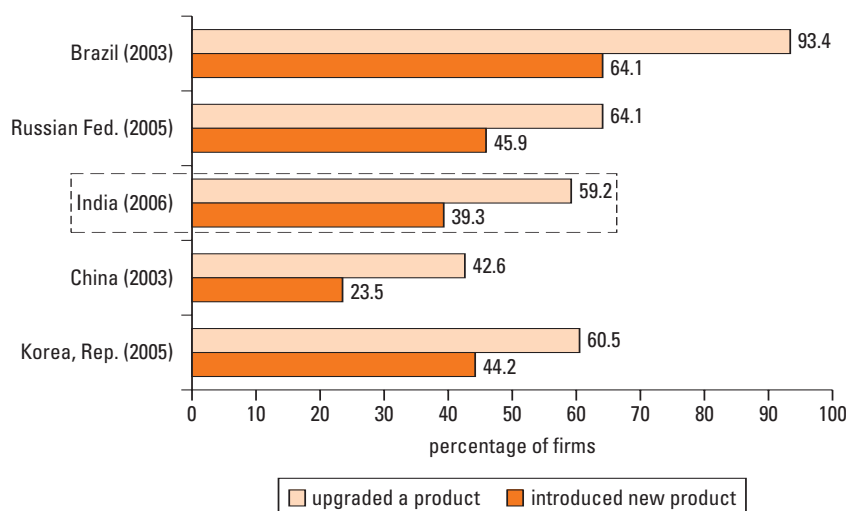
Innovation in Indian Manufacturing: Outputs, Inputs, and Productivity

Based on a 2006 survey of manufacturing enterprises, the extent of India's innovation outputs is not too dissimilar from those of comparator countries, with India in the mid-range. The India 2006 Enterprise Survey (World Bank 2006c) provides a basis for within- and cross-country analyses. It allows both links between innovation outputs and inputs and enterprise characteristics, and links between innovation activities and enterprise productivity.

Figure 1.5 shows the percentage of surveyed firms that responded positively to these questions on innovation outputs, relative to comparator countries.²² In India, 40 percent of firms had developed a major new product, while 62 percent had upgraded an existing product line. These criteria suggest that Indian firms have more innovation outputs than firms in China, but less than those in Brazil, Korea, and Russia. It is somewhat surprising that China scores so low on both measures and Brazil scores so high. The low scores for China may indicate that the Chinese are more active in copying than developing new products,²³ or are culturally more reluctant to consider novelty in their evolving products. In any event, India tends to rank in the lower-middle range relative to other countries.

Ultimately, innovation is not an end in itself but a means to productivity growth and higher living standards. Any discussion of how to enhance India's environment for innovation must be grounded in an appreciation of the role that innovation can play in promoting productivity and so national competitiveness, growth, and,

Figure 1.5 Innovation Outputs in Various Countries, 2003–06



Source: World Bank Enterprise Surveys.

ultimately, poverty reduction. For most enterprises in a developing country at India's level, the acquisition of global knowledge is expected to be more important for productivity than is the creation of domestic knowledge—because there is still so much to gain by drawing on the global knowledge frontier. Only for enterprises producing at the cutting edge of the global frontier in their sectors is creation the key source of competitiveness and growth. For all others not at the frontier, competitiveness by absorbing existing but better production methods not used locally is typically the best approach. In addition, absorption of knowledge (whether generated domestically or acquired from abroad) will do more to raise economic productivity than will creation of knowledge. Finally, knowledge contributes to productivity increases only

Table 1.4 Key Innovation-Related Findings of the India 2006 Enterprise Survey

Findings	Support
Enterprises engaged in creation are likely to be <i>larger, export-oriented, foreign-owned, ISO-certified</i> .	Firm size, exporting, and having ISO certification correlate strongly (1 percent level of significance) with the development of important new product lines.
Creation-oriented enterprises are concentrated in <i>drugs and pharmaceuticals, auto components, and garments</i> , though innovative firms exist in all sectors.	Sectors with the largest shares as listed Sectors with the lowest shares of firms developing new product lines are paper and wood, mining, mineral prospecting, metals, and leather.
Enterprises that absorb knowledge are more likely to be <i>larger, export-oriented, foreign-owned, ISO-certified</i> .	Listed firm characteristics correlate strongly with enterprises that acquired new technology, or paid royalties or licensing fees.
<i>Garment</i> enterprises are most likely to acquire new technology. <i>Drug and pharmaceutical</i> firms are most likely to pay royalties, use e-mail and computers, and subcontract R&D.	Sectors with the highest frequency of acquiring new technology, paying royalties, using e-mail, using computers, and subcontracting R&D as listed.
The most important channel for absorbing existing knowledge is through use of new machinery and equipment, followed by hiring of key personnel.	Some 70 percent of enterprises cite new machinery and equipment as the main source of absorbing technology. Those citing hiring key personnel as the main source total 10 percent.
A significant amount of informal, input-type creation activities beyond R&D occurs within enterprises.	The third most common source for acquiring new technology, cited by nearly 10 percent of firms, is by developing or adapting it within the firm. This figure jumps to 12 percent when development with an equipment or machinery supplier is added.
Measures of formal innovation inputs—both creation (R&D spending) and absorption (technology acquisition)—are closely and jointly associated with innovation outputs.	Larger, export-oriented, and ISO-certified firms as well as enterprises with a higher general level of manager education are more likely to spend on R&D and acquire new technology. These measures correlate strongly with developing new product lines. These measures are both significant even in the same probit regression, suggesting that they are complements rather than substitutes.

(continued)

Table 1.4 continued

Findings	Support
Innovation outputs are also associated with informal efforts to create and absorb knowledge.	A number of enterprises that developed or upgraded product lines did not conduct R&D or acquire technology: 39 percent of firms developed new products, and 59 percent upgraded existing product lines. But only 27 percent did formal R&D, only 16 percent reported acquiring a new technology, and only 34 percent had any R&D spending, acquired new technology, or paid royalty or licensing fees.
Innovation outputs are strongly associated with enterprise productivity.	Based on ordinary least squares estimation of productivity functions, development of new products has a strong and significant association with productivity.
Absorbing existing technology has a stronger, more significant association both with productivity than does spending on R&D.	Based on estimation of frontier production functions, separate measures of creation and absorption are significantly associated with narrowing the distance the frontier. The absorption effect is stronger and more significant, implying a bigger movement toward the frontier. When both absorption and creation are included, the latter becomes insignificant.

Source: Authors.

to the extent that it is used—hence, an emphasis on productive use is critical. Table 1.4 highlights key empirical findings from the Enterprise Survey on innovation inputs, outputs, and productivity.²⁴

The Enabling Environment for Innovation

The effort made by enterprises to create and absorb knowledge depends on the enabling environment for innovation. This section introduces some of the policies, institutions, and capabilities required to support innovation. Competition as the critical incentive for spurring innovation is discussed in detail, as are desirable principles for public financial support of innovation and institutional coordination.

The enabling environment for innovation should stimulate knowledge creation and absorption by enterprises to enhance competitiveness, exploit synergies between enterprises and other centers of knowledge, and provide incentives and support to supply inputs for innovation—particularly skills, information, and finance. The enabling environment for innovation comprises a country's innovation system as well as support for essential inputs as part of the country's broader investment climate (table 1.5). The innovation system, in turn, consists of policies, institutions, and capabilities that affect how enterprises create and absorb knowledge. Key support institutions for creating and commercializing knowledge include universities, public and private research centers, and policy think tanks. However, enterprises are at the center: if the private

Table 1.5 The Enabling Environment for Innovation: Policies, Institutions, and Capabilities

Components of enabling environment	Policies	Institutions	Capabilities
Creation and commercialization of new knowledge	• Policies to promote more private R&D ◦ Intellectual property rights regime ◦ Matching grants ◦ Tax subsidies • Public spending on R&D ◦ National mission programs ◦ Competitive grants ◦ Peer reviews • Support for pro-poor innovations	• Public labs, universities • Private R&D labs • IPR institutions • Technology transfer offices • Science and technology parks • Technology incubators • Research and education networks • Specialized nongovernmental institutions • Grassroots networks • Early-stage technology development finance and venture capital	• High-level human capital for R&D (scientists, engineers, technicians) • Techno-entrepreneurship
Diffusion and absorption of existing knowledge in new locations	• Openness to global knowledge flows ◦ Trade ◦ Foreign direct investment ◦ Technology licensing policy ◦ Internet access • Foreign education and attracting the diaspora	• Technical information services • Technology upgrading • Productivity organizations • Metrology, standards, testing, and quality control systems • National research and education networks • Networks at cluster level • Technology absorption finance for micro, small, and medium enterprises	• Formal education and skills • Engineering consulting firms • Business support services
Broader investment climate	• Competition and trade • Regulatory policies, especially toward infrastructure • Entrepreneurship support • Good rule of law • Macroeconomic stability	• Efficient financial system • Flexible labor market • Effective courts and judiciary • Market-responsive formal education institutions and lifelong learning system	• Literacy • Secondary and higher education graduates • Managers • Entrepreneurs

Source: Authors.

sector has little demand for knowledge, the innovation system cannot be effective. The main idea behind an innovation system is synergy between the major innovation players to create better, cheaper products that meet consumer needs.

Competition-Related Incentives to Improve Performance

Competition is critical for innovation. Product market competition encourages enterprises to innovate. The classic characterization of innovation dates to Joseph Schumpeter's notion of "creative destruction" (Schumpeter 1975 [1942]). Markets reward powerful creativity with extraordinary returns, and consumer demand turns genuine innovators into powerful incumbents. Because the best way to defeat such an incumbent is to produce a far superior product, competition drives the next

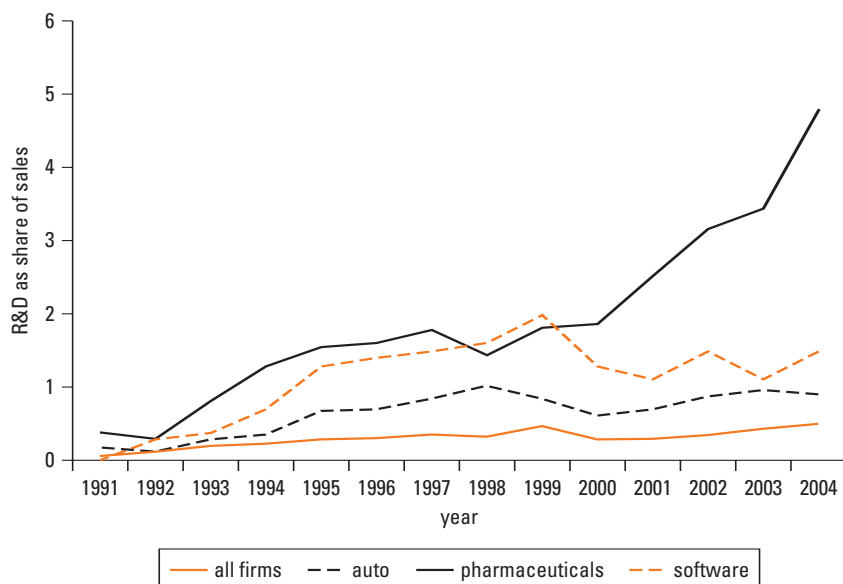
generation of innovators to “destroy” the incumbent’s market position by “creating” the next generation of products.

In well-functioning markets, investments by new entrants can stimulate larger, established enterprises with market power into greater efforts—leading them to likely be the first to achieve routine or incremental innovations. But new entrants are also more likely to effect revolutionary or leapfrog innovations that render heritage products obsolete. The speed and vigor of each group’s investment in innovation are driven by competition from others in its group and members of the other group. Government barriers that impede fluid entry and exit—that either overly protect incumbent firms and workers, or sour the rewards of successful innovation by challenging profitable gains—stultify the forces that make innovation a self-sustaining outcome of competition.

The importance of competition in stimulating knowledge creation and absorption is shown by comparing the situation in India before and after the business liberalization of the 1980s and trade liberalization of the 1990s. Before these reforms, India followed a policy of technological self-reliance. The large public R&D infrastructure was oriented toward developing technologies that supported small industries using indigenous materials, as well as large state enterprises in key sectors and in defense. Although many technologies were developed, most were not world-class. The private sector invested little in R&D and did not develop much globally competitive technology. After liberalization, Indian businesses began facing more competition and started increasing R&D investments (figure 1.6) (Rodrik 2005). Enterprise R&D

Figure 1.6 R&D Intensity of Indian Corporations in All Reporting Firms and Three Key Sectors, 1991–2004

(R&D spending as a percentage of sales)



Source: Compiled from data in Bowonder and others (2006).

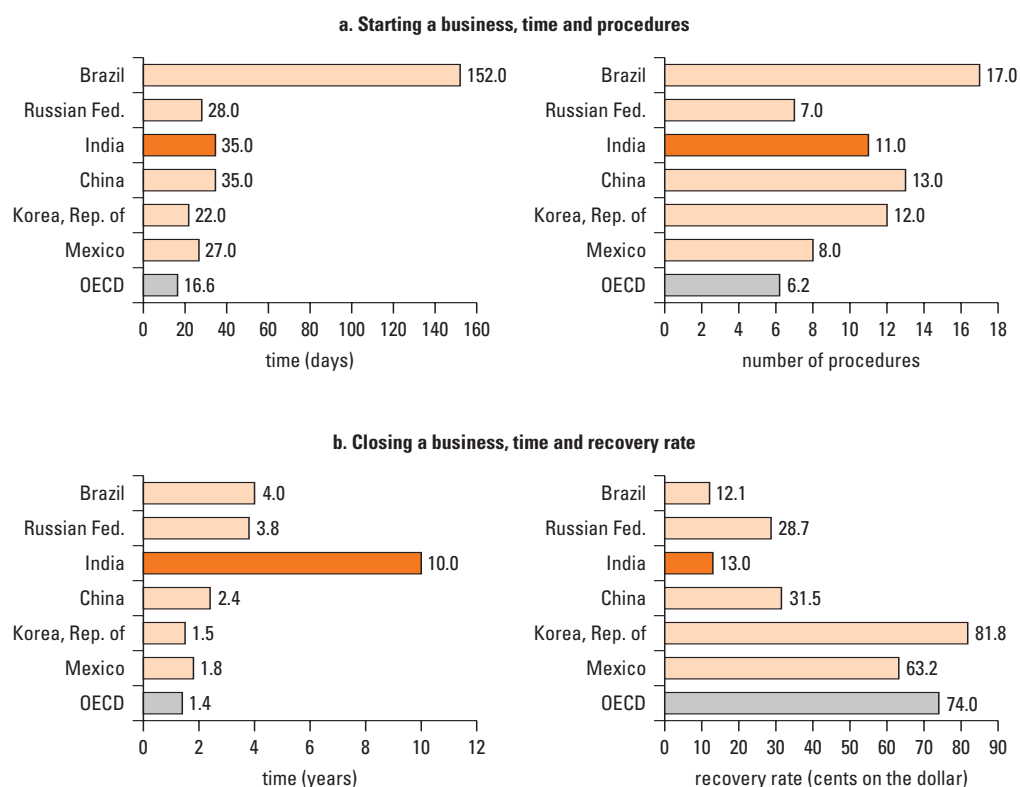
spending as a share of sales increased more than sevenfold, from 0.07 percent in 1991 to 0.53 percent in 2004. The sectors most open to competition—pharmaceuticals, software, auto components—have increased R&D spending the most.

In addition to sharp market incentives for competition and entrepreneurship, India needs to strengthen sociocultural norms for innovation. Entrepreneurship-friendly policies include ensuring that markets are open to competition from new entrants and that bankruptcy laws facilitate rapid recovery. In addition, sociocultural norms should place high social value on commercial success and see failure as an often indispensable learning experience that can eventually lead to business success. Finally, an unfortunate legacy of India's colonial past pertains to education. The British Raj fostered learning by memorization rather than creative problem solving, because the goal was to produce administrators who could help the British rule India more efficiently (Evaluerve 2006: 8). Recommendations to strengthen innovation-friendly sociocultural norms center on the following:

- *Campaigns to raise awareness of the importance of R&D for competitiveness and of commercialization of ideas for wealth creation and national welfare.* Mass media (TV, movies) and champions, role models, and mentors could be used for these efforts.
- *Dissemination of success stories of techno-entrepreneurs and other innovators* through publicity, prizes, and public recognition for cases that exemplify how knowledge has been turned into wealth or used to improve welfare.
- *High-profile awards for creative teachers* to encourage them to inspire creativity in their students, from primary and secondary school through vocational training and university education.

The most important policy change for increasing knowledge creation, commercialization, diffusion, and absorption is to sharpen competition among enterprises so that innovation becomes essential. Unencumbered entry and exit of enterprises are perhaps the most important stimuli to innovation. Limits on small firms and other barriers to entry and exit should be eased, imports further liberalized and firms pushed to export more, and opening to foreign competition expanded. Enterprise entry and expansion are also constrained by insufficient access to skilled labor, information and communication technology, finance, and other business services, especially power. These changes would also likely increase India's ability to tap into rapidly growing global knowledge (see chapters 2 and 3).

Although these are rather conventional recommendations that have been articulated many times,²⁵ they remain crucial. Such reforms will be resisted by vested interests who would be hurt by greater competition. Shorter-term recommendations, therefore, are to continue to open the Indian economy to global competition, encourage exports, increase domestic competition as quickly as is politically feasible, and to do so in a way that raises awareness of longer-run benefits and creates more support. Eventually, India should aspire to reach levels of trade and investment openness comparable to those of OECD countries, as China is doing. Such openness

Figure 1.7 Obstacles to Starting and Closing a Business in Various Countries, 2006

Source: World Bank 2006b.

Note: OECD = Organisation for Economic Co-operation and Development.

encourages enterprises to upgrade their productivity and competitiveness—and so provide better and cheaper products, create higher-paying jobs, and help reduce poverty.

Efforts to sharpen competition that improves performance should focus on facilitating entry and easing the reallocation of capital to more productive enterprises. Figure 1.7 shows some of the barriers to competition in India by comparing its regulations for enterprise entry and exit with those of comparator countries. As noted, streamlined regulations easing entry and exit are critical to stimulating innovation and productivity:

- *Starting a business* identifies the legal and bureaucratic hurdles that entrepreneurs must overcome to enter the market—here, the average time spent completing entry requirements and the number of procedures required to register a firm. Registration is typically critical for accessing a range of market infrastructure, including finance, physical infrastructure (electricity, water), and contract enforcement. The greater is the number of procedures, the more scope for enforcing them in uneven ways. In terms of the time required to start, India ranks second relative to benchmark countries at 35 days, tied with China and

ahead of Brazil, but significantly behind the OECD average of 17 days. (India is especially behind Australia and Canada, each requiring only two procedures and no more than 3 days.) Although India has significantly liberalized foreign direct investment (FDI) since the early 1990s, some sectors still have restrictions—with FDI either completely prohibited, as in retail, or sector caps added, as in telecommunications and insurance. Moreover, 326 products in various sectors are reserved for small industries, preventing entry by larger firms and normal expansion by the smaller ones.

- *Closing a business* tracks legal, procedural, and administrative bottlenecks in the bankruptcy process—here, the time required to complete a bankruptcy and how many cents on the dollar that claimants (creditors, tax authorities, employees) recover from insolvent firms. There is particular scope for facilitating exit in India in terms of time—10 years, the longest in the world—which is in stark contrast to China (2.4 years) and the OECD average (1.4 years). The focus on competition problems should occur at the local level, since that is where problems occur and pressures by vested interests are greatest. Indian authorities should recognize the variance across cities. Time and recovery rates are 8.3 years and 17.3 cents on the dollar in Bangalore—and 20.2 years and 5.1 cents in Kolkata (compared with an average recovery rate of 74 cents in OECD countries).²⁶

Reducing the stigma of failure and easing the reallocation of capital to more productive enterprises are among India's most important reforms. In India, capital is too scarce not to allow its reallocation to more productive uses as quickly as possible. Reforming exit policy reform through more efficient bankruptcy rules would help remove the stigma of failure and contribute to increased risk-taking and experimentation. The government has initiated reforms to improve the legal and regulatory framework for insolvency. The Companies (Second Amendment) Act 2002, expected to be presented in Parliament in 2007, removes a number of deficiencies. The J. J. Irani Committee reviewed the Second Amendment provisions and recommended further significant reforms to the Companies Act, including its insolvency and rehabilitation provisions. Implementation of these recommendations would significantly improve the insolvency regime.

In addition, initiatives have been launched to computerize company registries and introduce information technology and case management tools in courts. Authorities also need to build capacity among all participants in the process—judges, liquidators, creditors, operating agencies, investigators, auditors, valuers, and oversight bodies. Systematic education and certification for liquidators are also needed to ensure professionalism and develop insolvency practices. Finally, modernizing the Industrial Disputes Act to reduce the bias toward adjudicating disputes and increase flexibility for employers in hiring and firing in a way that also protects worker rights would help close less productive enterprises and enable capital to flow to more productive ones.

Public policy must ultimately promote both competition and collaboration. A main theme of this book is the effectiveness of market forces in inducing innovation,

and the need to strengthen and extend the domain of market competition so that innovation can flourish. However, an enterprise's ability to generate new products and processes depends on two complementary processes—analysis and interpretation.²⁷ On the one hand, innovation requires analysis, where alternative outcomes can be clearly defined and distinguished from one another—an engineering and management-based project approach of problem solving and rational decision making. On the other hand, innovation also requires interpretation and trust, where the possible outcomes are unknown—a more open-ended process approach that requires drawing various actors together, initiating and guiding conversations to allow economic actors to understand where they have the same and where they have different interests. Both processes are necessary for successful innovation, with the latter especially critical when the problem is not yet well defined. But while analysis is spurred by competition, interpretation benefits from collaboration, a sheltered space from competition where the risk of private appropriation of information is reduced and where misunderstandings have fewer direct consequences. Accordingly, there is a need to build an effective institutional infrastructure that allows appropriate collaboration and networking. The breakdown of bureaucratic silos within the public sector, as well as the improvement of linkages between universities, public and private R&D labs, and private enterprise through consortia, is part of this institutional infrastructure.

Principles for Pragmatic Coordination of Innovation Support Programs

Coordinating existing and new programs that support innovation would benefit from a new approach—one that builds an effective institutional infrastructure that helps the various elements form a coherent system.²⁸ The main idea behind a national innovation system is collaboration and synergy among enterprises, universities, research institutes, and government. Yet the reality in most countries, including India, is of ivory towers—and additional silos within each—with insufficient incentive to interact.

Most innovation systems resemble a jigsaw puzzle. Many pieces of the puzzle (a vibrant private sector, solid public research institutes, a rapidly growing venture capital industry) already exist in India. The challenge is putting the pieces together in a coherent whole. In designing a new national innovation program, India should not introduce more targeted programs that, although individually useful, would worsen the jigsaw problem. For example, a typical well-intentioned solution is to coordinate the pieces top-down through an interministerial council. However, international experience suggests that such attempts largely fail: councils usually become cartels of established interests, while new ministries become efficient at creating and defending their own turf. The drive for top-down coordination is a symptom that something is wrong with the incentives of enterprises, universities, research institutes, and government entities. In fact, as economies have become more complex, top-down coordination has posed more of a problem.

Box 1.2 Innovation Foresight Processes in Canada and the Netherlands

Canada. *Technology road maps for industry R&D.* Technology road mapping is a planning process driven by the projected needs of tomorrow's markets. It helps companies identify, select, and develop technology alternatives to satisfy future service, product, and operational needs. Through this process, companies in a given sector can pool their resources and work with academia and governments to look 5–10 years into the future and determine what their market will require. The technology road map process is led by industry and facilitated by Industry Canada, Canada's Ministry of Industry.

The Strategic Project Grants Program of the Natural Sciences and Engineering Research Council of Canada (NSERC). This program funds project research in target areas of national importance and emerging areas of potential significance to Canada. The research is at an early stage, with the potential to lead to breakthrough discoveries. Targeted areas are identified in consultation with experts from all sectors.

Identifying opportunities for leapfrogging. A new body has been created by the NSERC to advise on areas where Canada may be able to leapfrog to the front ranks of research in the natural sciences and engineering.

The Netherlands. Foresight processes are conducted by a number of advisory bodies. The Royal Netherlands Academy of Arts and Science engages in foresight processes from the perspective of promising scientific developments. Several other bodies conduct or are involved in foresight processes from the perspective of knowledge demand. For instance, the Sector Councils, which cover a broad array of societal sectors, draw up research agendas based on inputs from government, scientists, and the sectors involved. A recent example of a priority-setting mechanism with a direct follow-up in investment funding is the ICES-KIS program, which involves extensive consultations with various stakeholders.

Source: Authors.

A possible solution of pragmatic coordination involves combining three coordination elements, drawing on lessons from Chile, China, and Finland, among others:

- *Conducting regular, independent evaluations with international benchmarking.* Such evaluations link the assessed impacts of programs—relative to international benchmarks—to decisions on the allocation of budget resources. Best practice is to allocate 3–5 percent of a program's budget to evaluation. Although there will be resistance to evaluating programs whose inefficiency is likely to be revealed, impartial and public access to results will provide a strong disciplining effect and help push for changes to improve performance. This kind of evaluation must be driven by “champions”—individuals willing to risk their reputations on the results of reforms. An informal group of champions in key innovation entities exists in India, and should include national leaders from industry, research centers, universities, and government, as well as leaders from the diaspora. For policy and programmatic ideas to be turned into actions, the champions must include key national decision makers in their deliberations.

- *Introducing new programs through strategic pilots.* Because scaling up, not piloting, is the main goal of new programs, pilots should be selected based on their scalability and diffusion, as is done in China. This is why they are called “strategic” pilots.
- *Fostering innovation foresight for future societal needs to inform current decisions.* Innovation foresight links a consensus view on the future needs of society at large with new tools of science and technology to address those needs. Early efforts at using innovation foresight approaches were conducted in the United Kingdom in the 1990s. The first resulted in the unexpected articulation of the widespread ramifications of an aging population and the possibilities of innovation in meeting those needs. Since then, foresight processes have been adopted elsewhere and have proven particularly useful in defining long-term needs and developing the creative synergies from which innovation emerges (box 1.2). A nationwide foresight process in India with collaborative interaction of a group of industry, government, civil society, and research community representatives could start with a focus on thematic national challenges, such as access to clean water or road transport congestion in cities.

Notes

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1. The term “economic dualism” is used here not in the sense of Nobel laureate Arthur Lewis’ 1954 model of labor market dualism, but rather to emphasize the stark contrast between the “two Indias.”
2. See Planning Commission (2006, Table 2) where an all-India consumption poverty head count ratio of 27.8 percent is reported based on the 2004–05 National Sample Survey, with poverty in the worst state rising to 46.5 percent.
3. See World Bank (2006h) and Planning Commission (2006, Table 2): all-India female illiteracy of 46.3 percent is calculated based on information from the 2001 Census, with illiteracy in the worst state rising to 66.9 percent.
4. For economic theory and empirical bases for the linkage between competition, innovation, productivity growth, and overall economic growth, see Aghion (2006), Aghion, Bloom, and others (2005), and Aghion, Blundell, and others (2006).
5. As reported in Planning Commission (2006), the consumption poverty head count ratio has fallen from 36.0 percent in 1993–94 to 27.8 percent in 2004–05. Although there is no established causal link between innovation and poverty alleviation, it is plausible to presume that innovation can have a longer-term impact on poverty by increasing growth, as well as a more direct impact through pro-poor innovation efforts.
6. While informality is often deemed to be driven by high formal sector taxes and restrictive rules and regulations, the dualism referred to here is driven by skills gaps and other impediments to knowledge creation, absorption, and use.
7. Defining formal and informal employment is difficult. The formal sector is usually more modern, subject to more government regulation and taxation, and uses more updated production and organization techniques than the informal (also known as traditional) sector. This section uses estimates from World Bank (2006f) that compare data from five-year National Statistical Office surveys with the population censuses conducted every decade, and data from the Annual Survey of Industries for the organized manufacturing sector (see table A.1 in the technical appendix).

In World Bank (2006d: 7), the workforce estimate is roughly 390 million for 2003, with only 8 million employed in the formal private sector. According to the latest National Sample Survey data for 2004–05, the size of India's workforce was 457.4 million; although private formal employment has definitely grown since 2003, an updated figure is not available.

8. See in particular World Bank (2006e).
9. See Bosworth and Collins (2006).
10. There is much less international, comparable information on the inputs and outputs of informal creation and on knowledge diffusion and absorption by enterprises.
11. The rankings presented in the following paragraphs, based on quantitative measures, are more sober than, for instance, the subjective assessments of international business leaders on India's innovation potential in World Economic Forum (2006).
12. Inspired by the comparison of the so-called BRICs economies of Brazil, Russia, India, and China initiated by reports from Goldman Sachs, this study uses a somewhat larger set of comparator countries wherever data are available, and reports figures in the BRICKM order: Brazil, Russia, India, China, Korea, and Mexico. See *Business Week's* report (April 24, 2006) on the world's most innovative companies, based on a global survey of 1,070 senior managers in early 2006.
13. These are 2 of the top 10 reasons India can innovate, according to Govindarajan (2006).
14. http://www.investmentcommission.in/human_capital.htm.
15. By including own estimates of domestic and especially multinational corporation spending on R&D for 2003 and beyond, Evalueserve (2006) estimates that total R&D spending in India was 1.08 percent of GDP in 2005, and forecasts that this figure will rise to 1.75 percent of GDP by 2010.
16. A dollar of R&D spending goes further in India—or, conversely, R&D in India can be conducted at roughly one-fourth of the cost in the United States. See Evalueserve (2006).
17. Figures for 2005 and 2006 are projections based on continuation of the observed 2000–04 growth.
18. See Evalueserve (2006) who have added to the Indian Department of Science and Technology figures for 2003–05 (fiscal years 2003–04 and 2005–06) rough estimates based on surveys of domestic private enterprises and MNCs in sectors such as IT services, electronics and electrical equipment, chemicals, drugs and pharmaceuticals, biotech, and automotive engineering services.
19. Based on Abramson (2007: 23).
20. To make international comparisons on patenting, it is necessary to standardize for the patent regime because of national differences in what can be patented. Thus, it is useful to examine patents submitted to the U.S. Patent Office, because the United States represented the largest global market until the European Community recently overtook it.
21. These very aggregate measures are just a rough proxy because they do not control for the importance of the articles or the patents. In addition, issue can be taken with the relevance of U.S. patents as the measure. Still, these measures provide a characterization of India's broad performance and strengths relative to other countries.
22. The survey's best available proxy for innovation output is whether an enterprise developed an important new product line in the past two years. A second, broader proxy for innovation is whether an enterprise upgraded an existing product line. Neither of these enables inferences about whether the products were truly new to the world or simply new to India. Most "innovative" products are probably not new to India but new only to the enterprise or to its market. The latter is more likely in cases where the relevant market is local or regional, rather than national. The extent of novelty also could vary across enterprises depending on how the question was asked and what responding managers perceived as being "new."
23. See, for instance, *Economist* (2006).
24. R&D spending (or whether any R&D is done within the firm or subcontracted) is used as a proxy for creation activities, while reporting on having "acquired new technology over the past two years that either substantially changed the way that main products are produced or allowed the production of new products" is the main proxy for absorption activities (also paying royalties or licensing fees, using Web sites, and the like). See technical appendix tables A.2 and A.3 for key regression results.

25. See in particular the excellent multisector study by McKinsey Global Institute (2001), which remains as relevant today as it was upon publication.
26. For data highlighting variations in restraints across cities in specific countries, see World Bank (2006a: 28; 2007a).
27. See, for instance, Lester and Piore (2004).
28. This section draws from, among others, Kuznetsov (2006) and World Bank (2007b). Examples of how strengthening the institutional infrastructure becomes a key part of the action agenda for fostering innovation are provided in World Bank (2007b: 100–04).

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Creating and Commercializing Knowledge

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Recognizing the economic importance of generating, commercializing, and absorbing research and development (R&D), over the past 10–15 years, the government has created a number of R&D support programs. However, the effectiveness of these programs must be systematically evaluated and strengthened. Support has included programs for R&D by public laboratories; joint projects between public labs and enterprises; grants, loans, and equity participation for the creation of knowledge-based companies; commercialization of R&D outputs; skills and quality upgrading; support for intellectual property rights (IPR); and development of technology incubators and science and technology parks.¹

Although these programs have achieved significant successes, their effectiveness has not matched the needs of the Indian economy or been commensurate with the resources invested in them. This imbalance is not only a loss for specific programs but, more important, represents many missed opportunities for the nation. Private sector involvement has been minimal: most programs have been operated and managed by government institutions. Public institutions typically suffer from complex, overlapping structures for policy making and decision making. This public sector approach reflects a preference for government ownership and management of the initiatives, rather than leveraging private sector capacity to provide investments, modern management, risk taking, and needed skills, designs, and operational flexibility.

The rigid, bureaucratic resource allocation procedures, combined with the lack of risk taking and clear accountability in many public institutions, may be the main reasons for the limited effectiveness of the government's R&D programs. Most critically, programs should be subjected to sufficiently regular, independent, performance-based monitoring and evaluation, with international benchmarking of their inputs, management practices, outcomes, and impacts.²

The government is developing a new approach that leverages the strength of the public as well as private sectors in the design and operation of all public R&D support programs. As part of this program, the government needs to provide a “light-touch” policy and regulatory framework that encourages the private sector to undertake initiatives with sufficient speed-to-market to benefit the country economically. This framework should receive appropriate financial support—to encourage private firms to take risks that they would otherwise not take. The private sector should be called upon to manage programs with appropriate checks and balances as well as with performance standards and monitoring.

In addition, all public R&D support programs must be periodically subjected to thorough independent reviews and evaluations by national and international experts. The programs should be benchmarked against relevant features of the most effective programs of other countries. Based on these evaluations, the programs should be expanded, restructured, or closed, to ensure maximum benefits from government support. Efforts should also be made to consolidate the many existing programs into a small number of simplified framework programs, coupled with a nationwide awareness program. Although this new approach is being implemented, it needs to be strengthened, expanded, and expedited.

Increasing Private R&D Efforts

The world has acknowledged India’s R&D potential. More than 300 multinational corporations (MNCs) have set up R&D and technical centers in India. Despite their recent increases in R&D spending, national corporations and other domestic enterprises are not systematically exploiting this potential to India’s advantage. This section explores the role of public policy in increasing private R&D efforts.

Recent Trends in Private R&D and Assessment

Since liberalization, Indian indigenous R&D spending at the enterprise level has grown significantly. In 1991, indigenous enterprise R&D spending as a share of sales was less than 0.1 percent.³ By 2004 that share was more than 0.5 percent. Although this was a significant increase in less than 15 years, it remains low by international standards. Most indigenous Indian companies are funding little R&D on their own. Only three Indian companies—Ranbaxy and Dr. Reddy’s Lab in pharmaceuticals and Tata Motors—are among the world’s top 1,250 companies when it comes to R&D investment (U.K. Department of Trade and Industry 2006).

Indigenous enterprise R&D and innovation are on the rise—and above the Indian average in the pharmaceutical, automotive, and information technology (IT) and software sectors. Not surprisingly, these are the sectors where India has been facing the most competition from MNCs and a more demanding international market, to which many domestic enterprises are beginning to expand exports. Pharmaceuticals is the country’s most R&D-intensive sector, with the share of R&D

Box 2.1 Private R&D in Pharmaceuticals

Little R&D was conducted in-house by Indian pharmaceutical companies in the 1950s and 1960s. The 1970 Patent Act created an incentive for firms to do R&D, focused on finding new processes for known drugs (because only processes, not products, were patentable under the legislation) and substituting local for imported inputs wherever possible. Based on existing capabilities and with the liberalization of the 1990s, some firms began to focus on novel drug delivery systems. By the late 1990s, some leading companies embarked on drug product discovery. There has been an emergence of technologically competent medium-size firms manufacturing active pharmaceutical ingredients and intermediates to global standards for MNCs and large Indian generic companies. Some are undertaking custom synthesis and contract manufacturing for patented molecules for international clients based on their own process know-how.

Some of the leading firms have shifted their strategy from “business-driven innovation” to “research-driven business” aimed at developing innovative, non-infringing processes, novel drug delivery systems, new chemical entities, and biopharmaceuticals. In 2003, Indian pharmaceutical companies accounted for the most Drug Master Files applications (126) with the U.S. Food and Drug Administration (USFDA)—more than China, Israel, Italy, and Spain combined—and had the largest number of USFDA-approved manufacturing facilities (60) outside the United States.

In the early 2000s, Indian pharmaceutical companies sought to license “lead molecules” that they had discovered to major global players at the preclinical stage because of the heavy investments and risks involved in further developing them. But the scene has since changed. India’s 10 top pharmaceutical companies are now investing heavily in R&D and developing clinical trials of lead molecules on their own, with more than 50 new drug developments in the pipeline. The rate of new drug development is accelerating rapidly, as even medium-size companies are increasing R&D spending for new drug discovery. In addition, Indian companies are entering into R&D alliances with international pharmaceutical companies. Some, like Nicholas Piramal Labs, are even buying up foreign pharmaceutical firms and expanding production in the United States.

Source: Authors.

relative to sales jumping from 0.4 percent in 1991 to 4.8 percent in 2004 (box 2.1). India’s pharmaceutical industry has developed world-class capability and become a major innovator. India’s three top pharmaceutical firms (Dr. Reddy’s, Sun Pharmaceuticals, Ranbaxy) invested 12–18 percent of sales in R&D in fiscal 2006.⁴ These levels are comparable to those of some of the world’s leading pharmaceutical firms, such as Pfizer (14.6 percent) and GlaxoSmithKline (14.0 percent).

India’s automotive firms increased R&D spending from 0.2 percent of sales in 1991 to 0.9 percent in 2004. Indian IT and software firms increased R&D spending from almost nothing in 1991 to 1.5 percent of sales in 2004. Ramco Systems raised R&D spending the most, by 40 percent, but large software firms such as HCL

(2.5 percent) and Infosys (0.9 percent) had much lower increases. In 2005, Wipro, one of India's premier global IT service companies, generated more than \$100 million in revenues through its innovation initiative and 40 Centers of Excellence—which have about 500 employees working on innovation-related projects. Innovation at these centers has focused on process improvements, new service lines, and R&D. Wipro's most recent innovation is a Global Command Center that offers shared service solutions through a remote location.

The private sector increasingly recognizes the need for further innovation. A recent survey of 83 top executives representing all major manufacturing sectors found that they are increasing efforts to innovate. The results are as follows:

- 82 percent believed that generating organic growth through innovation is essential for success in their industry;
- 70 percent said that their companies would increase spending on innovation in 2006; and
- 71 percent felt that lack of collaboration between industry and research institutes was the main hurdle to innovation in India (CII and BCG 2005).

The survey also found that the key challenges faced by companies included measuring returns to innovation, moving quickly from idea generation to initial sales (commercialization and launch), and balancing risks, time frames, and returns across a portfolio of new projects. These findings imply that better monitoring and management training and tools for innovation are becoming increasingly important for Indian firms.

MNCs have discovered that India is an excellent location for R&D. In several international surveys, investors have ranked India as their preferred destination for locating innovation centers. (See, for example, Silverthorne [2005], who reports that 69 percent of firms consider India their preferred site—compared with 8 percent for China.) One of the country's advantages is that the total annual payroll cost of an Indian scientist or engineer is roughly \$22,600 a year, compared with \$90,000 in the United States—or roughly a quarter of the cost.⁵ Global firms are using three strategies to source innovations in India: locating innovation centers in India through fully owned local subsidiaries, outsourcing innovations to Indian research centers and firms, and acquiring innovative entrepreneurial firms and start-ups (Bowonder and others 2006).

Between 1998 and 2003, MNCs made \$1.3 billion in R&D investments in India. More than 300 MNCs are setting up R&D and technical centers in India. They employ over 80,000 scientists and engineers and spend about \$4 billion a year. Planned investment totals \$4.7 billion (based on approvals by the Secretariat for Industrial Approvals).⁶ The United States accounts for more than half the number of companies and 72 percent of the investment, and 63 percent of the planned investment. Others key countries include France, Germany, and the United Kingdom, as well as Canada, China, Denmark, Japan, the Republic of Korea, the Netherlands, Norway, South Africa, Sweden, and Switzerland. Almost half of the centers are in

Bangalore, followed by New Delhi and Mumbai. The main areas are computer and IT, R&D software, engineering design (automotive, consumer durables, aerospace), chemical design (molecules, chemical structures), and agriculture and biotechnology (seeds, food, enzymes). Some 415 patents from India have been filed by these firms with the U.S. Patent Office.⁷

The growth of MNC R&D centers generates positive spillovers to the Indian economy, with the demonstration effect to indigenous corporations being the most critical. The net effect of MNC R&D investments is hard to discern, though likely strongly positive over the longer term. It depends on the positive and negative externalities on the Indian economy, and there are little data on this.⁸ The most important positive spillover is likely the new enterprises that will ultimately be set up or supported by the scientists and engineers who gain experience in the R&D labs, in pursuit of new ideas not directly of relevance or interest to the MNCs. Another important positive effect is the demonstration both to the government and to domestic firms that India has valuable assets that they should be exploiting more effectively. India's attractiveness is a testament to the quality and cost-effectiveness of its current stock of scientific and engineering talent (box 2.2). Moreover, MNC-hired scientists and engineers are likely to receive higher salaries and benefits than they would from working for the government, universities, or domestic firms. In addition, working in MNC research centers provides valuable training for Indian scientists and engineers in the increasingly important area of innovation management—a key need for domestic firms. To the extent that these scientists and engineers collaborate with local firms or leave MNCs to set up their own firms or work for domestic enterprises or government labs, this training could provide India with a large positive externality.

Box 2.2 R&D Links between Multinational Corporations and Academia

The huge influx of foreign direct investment (FDI) in India's electronics and IT sectors has led to a growing number of university-industry partnerships for undertaking R&D. The Indian Institutes of Technologies (IITs), Indian Institutes of Science (IISc), and other specialty institutes are hubs for innovation fueled by investments from overseas IT companies.

The following are illustrative examples of the close association between MNCs and academia in India. The IBM India Research Laboratory, set up at IIT Delhi, is undertaking significant activities in many IT areas, including information management, e-commerce, distributed computing, life sciences, user interaction, and software engineering. The Society for Innovation and Development (SID) was set up in 1991 as the industry interaction arm of the IISc, Bangalore. Since then, SID has initiated R&D programs for IT and electronics companies, including Sun Microsystems, Honeywell, Nokia, and Cookson Electronics.

Source: Authors.

Possible short-term negative spillovers include diverting talent away from India-specific needs and raising the cost of talent for indigenous firms. Although some MNC research may be focused on the needs of the domestic market, the bulk of it is likely for the MNCs' global operations. Thus, there could be a direct opportunity cost to India in the short term. In addition, the strong rise in demand for Indian scientists and engineers is leading to rapidly rising salaries and strong competition for their talent. This talent pool is not as large as is commonly thought (see chapter 5), and salaries are rising very quickly. Thus, a secondary effect is that the rise in salaries induced by the increasing demand by the MNCs may be making it more expensive for the government, universities, and domestic firms to do R&D. Although large domestic firms may be able to compete, that may not be possible for smaller firms, public labs, and universities. As a result they could incur a cost and a net loss in the short term—except to the extent that they may have positive interactions and contract work from the growing research demand of the MNCs.⁹

The net effect of the rapid rise of MNC research centers in India is complex and requires careful analysis, though it is likely to be strongly positive over the longer term. It would be useful to conduct additional surveys to better understand the focus of the research by the MNCs and the career paths of the Indian scientists and engineers working for them. In the meantime there are two policy implications. First, it is not necessarily in India's best interest for the government to offer more incentives to MNCs to locate R&D in India, as some have proposed. A neutral policy that does not favor foreign over domestic firms may be more appropriate unless further analysis shows that the research by foreign firms has greater positive externalities—for strengthening India's overall research capability and economic returns to the country. Second, more should be done to increase the supply of quality scientists and engineers, because there is clearly an increasing supply constraint that will undermine the growth of R&D by Indian firms as well as by MNCs in India. India's large demographic dividend should lead to a sharp supply response over the longer term with appropriate incentives for the development of higher-end skills, with likely enormous benefits to the Indian economy from greater exposure to MNCs.

Assessment of Government Programs to Promote Private R&D

Of government programs supporting early-stage technology development (ESTD) by formal private enterprises, the Sponsored Research and Development (SPREAD) program has been an early success—though other initiatives are increasingly trying to promote public-private partnerships. The case for public support for private innovative efforts revolves around the social returns from these investments exceeding the private ones. On the financing side, the positive spillovers to the rest of the economy from innovation do not allow inventors to capture all benefits; hence, there will be underinvestment. In addition, there is an asymmetry in the information available to inventors and investors evaluating innovations, with the due diligence

efforts required to close this information gap typically leading investors to wait and see the commercial outcomes before investing.¹⁰

To help address these market failures, government programs in developed economies typically provide support to ESTD through grants—and especially matching grants to enterprises—that encourage public-private risk-sharing, are additional, and orient the selection process toward outcomes with high commercial impact. India's SPREAD is an early ESTD program that has been directed exclusively at private enterprises, with an explicit requirement for collaboration with public research institutes, and has been independently evaluated as successful.¹¹ The new Small Business Innovation Research Initiative (SBIRI) program of the Department of Biotechnology, which provides matching grants, appears to be exactly the type of scheme needed more broadly across other sectors of the economy, with modifications as appropriate based on early independent evaluation. And existing programs—such as the Technology Information Forecasting and Assessment Council (TIFAC) Home Grown Technology (HGT) program, Department of Scientific and Industrial Research (DSIR) Technology Development and Demonstration Program (TDDP), Department of Science and Technology (DST) Pharmaceuticals R&D Support Fund (PRDSF), and DSIR-TIFAC Techno-entrepreneurs Promotion Program (TePP)—are considering moving in the direction of SBIRI-type matching grant support (see table 2.1).

Fiscal incentives to promote R&D appear ineffective. Fiscal incentives currently available include the following:

- Income tax relief for R&D spending by industry
- Weighted tax deductions for publicly sponsored R&D and approved in-house R&D projects
- Customs duty exemptions on capital equipment, spare parts, accessories, and consumables imported for R&D by approved R&D units, institutions, and scientific and industrial research organizations (SIROs)
- Excise duty waivers on domestic items purchased by approved institutions and SIROs for R&D
- Excise duty waivers for three years on goods produced based on domestically developed technologies and patented in any two of the following countries: India, Japan, the United States, or any EU member
- Accelerated depreciation allowances on plant and machinery setups based on domestic technology
- Customs duty exemptions on imports for R&D projects supported by the government
- A 10-year tax holiday for commercial R&D companies.

There has been a lack of monitoring and accountability of these incentives and their outcomes. Moreover, industry has not used them to any significant degree. It is

Table 2.1 Programs to Promote Private R&D

Program	Description
Sponsored Research and Development (SPREAD)	
Agency/year	ICICI, 1989
Objective	Encourage collaboration between industrial firms and public research institutions
Background	Initially managed by ICICI Bank's Technology Cell After initial funding was fully used by 1997, the program was relaunched by ICICI in 2002 using reflows from successful projects, funding 30 projects through 2005—though it remains small and does not share in recipients' upside potential.
Funding	\$15 million (initial)
Support	Soft loans for up to half of project costs
Target	R&D projects undertaken by companies in association with technology institutions (public research institutions, industry association labs, technology training entities) Almost 80 percent of firms were small and medium enterprises (SMEs).
Achievements	Financed more than 100 companies, including over a dozen start-up companies in high-tech sectors such as biotechnology, electronics, and advanced manufacturing Had a particularly significant impact on India's biotechnology industry and continues to be a main source of support funds for ESTD in the sector
Home Grown Technology (HGT) Program	
Agency/year	Technology Information Forecasting and Assessment Council (TIFAC), 1992
Objective	Supports ESTD of indigenous technologies; strengthens links between research institutions and industry
Background	Originally provided up to half of project costs as soft loans Refocused in 2005 to support highly innovative, high-risk technologies through matching grants
Support	Start-ups and SMEs receive up to 50 percent grants for project costs Collaborations, where R&D institutions or universities receive up to 80 percent grants, with remaining funds coming from an enterprise partner or user organization
Target	Support was initially given primarily to laboratories; later, program gradually shifted focus to encourage SMEs to take on R&D projects.

(continued)

Table 2.1 continued

Program	Description
Achievements	Impact has been small relative to economywide needs: during 1993–2005, HGT supported 34 enterprise-specific projects, 22 enterprise-lab collaborations, and 21 laboratory projects. ^a
Technology Development and Demonstration Program (TDDP)	
Agency/year	Department of Scientific and Industrial Research (DSIR), 1993
Objective	Seeks to promote ESTD by sharing risk with innovators and forging industry-institute collaboration
Background	Previously known as Program Aimed at Technological Self-Reliance (PATSER) An independent evaluation of TDDP and other DSIR support programs was launched by the Indian Institute of Management–Bangalore in October 2006, with findings expected by March 2007. Depending on the results of the evaluation, there is interest in merging the two programs under a common matching grants scheme.
Support	Soft loans for up to half of project costs for research, development, design, and engineering
Target	Selected proposals either by enterprises on their own or jointly with research or education institutions
Achievements	More than 180 projects—a small amount relative to economywide needs—have been supported, led by either private or public enterprises covering products and processes across industrial sectors such as electronics, mechanical engineering, metallurgy, embedded software, and pharmaceuticals. ^b
Techno-entrepreneurs Promotion Program (TePP)	
Agency/year	Department of Scientific and Industrial Research and TIFAC, 1998
Objective	Help individual innovators become technology-based entrepreneurs (“technopreneurs”) by converting ideas into working prototypes or processes
Background	Provides ESTD support for individual innovators, but with significantly less risk sharing by the private sector Although TePP appears to be a successful collaboration between two institutional entities within the Ministry of Science and Technology, funding has not been seamlessly combined, and outcomes are still reported separately, with the 151 projects broken down into 82 supported by DSIR and 69 by TIFAC.

(continued)

Table 2.1 continued

Program	Description
Support	Provides 90 percent of project costs as grants, with only 10 percent borne by inventor Helps inventors identify and network with appropriate R&D and academic institutions for guidance, technical consultancy, and development of prototypes, then helps with securing and filing intellectual property rights and linking with appropriate sources of financing for commercialization of products
Target	Individual innovators
Achievements	Over 1998–2006, received more than 5,500 applications; 1,200 of these have been assessed. 151 projects have been supported and about half have been successfully deployed.
Pharmaceuticals R&D Support Fund (PRDSF)	
Agency/year	Department of Science and Technology, 2004
Objective	Support ESTD in the pharmaceuticals sector
Funding	Initial support of Rs 150 crore (\$36.5 million)
Support	Up to 70 percent of project cost as unsecured soft loans For collaborative R&D projects, roughly 50 percent of project costs are in the form of 100 percent grants to the R&D institution's capital expenditures and 70 percent grants for the institution's operating expenditures (with the enterprise covering 100 percent of its research costs and 30 percent of the institution's operating expenditures).
Target	Pharmaceutical enterprises
Small Business Innovation Research Initiative (SBIRI)	
Agency/year	Department of Biotechnology, 2006
Objective	Seeks to meet the ESTD funding needs of private biotechnology enterprises
Background	Still-untested program by the Department of Biotechnology Competitive program that provides matching grants to enterprises with fewer than 500 employees to stimulate technology development—modeled on the U.S. Small Business Innovation Research program
Support	Supports start-up phase I with 80 percent grant support (for project costs up to Rs 25 lakh, or \$0.6 million) Supports phase II development-for-commercialization-potential, with soft loans for enterprises and grants for public partners
Target	Restricted to biotechnology and covers all biotech areas related to health care, agriculture, industrial processes, environmental biotechnology, and biomedical devices and instruments

(continued)

Table 2.1 continued

Program	Description
	Open to individual enterprises (start-ups by science entrepreneurs and existing enterprises based on in-house R&D), groups of enterprises, and public-private partnerships (joint proposals by enterprises and R&D organizations and institutions, which are given preference)

Source: Authors, based on Ministry of Science and Technology materials.

Note: Year refers to the date the program was established.

- a. Over 1993–2005 TIFAC, under HGT, contributed Rs 34.6 crore (\$8.4 million) and catalyzed industry contributions of about Rs 70 crore (\$17 million).
 b. DSIR, under TDDP (formerly PATSER), has contributed about Rs 80 crore (\$19.5 million) to total project costs of around Rs 250 crore (\$61 million).

estimated that the total benefits derived will not exceed Rs 1,000 crore (\$245 million) (Bhojwani 2006). This perhaps reflects the high transaction costs involved in deriving their benefits and the low importance that R&D has in corporate planning and strategy (see OECD 2003).

Recommendations

To increase private R&D efforts, reform is needed in the following two key areas:

1. *Undertaking a study on MNC spillovers and adjusting incentives accordingly.* A study on the externalities of MNC R&D centers would help indicate how best to adjust existing incentives, in particular how to ensure that SMEs can still employ competent technical personnel as the talent gap is being addressed (see chapter 5).
2. *Consolidating and expanding appropriate ESTD programs, and developing pro-innovation public procurement policies.* To support private R&D more effectively, the government should build on the independent evaluation of DSIR programs launched in October 2006 and undertake a comprehensive review of existing ESTD programs using international benchmarking. Based on these reviews, programmatic reforms could include establishing a matching grant program that builds on SPREAD and SBIRI programs. SPREAD has been a success; it should now be replicated on a larger scale and broader scope, with alternative institutional structures as appropriate. The expanded program should offer matching grants, soft loans, or both, perhaps restricted to SMEs in manufacturing and services—ideally under one simplified, consolidated program that would then benefit from significant national awareness-raising efforts. Matching grants would encourage firms to undertake higher-risk, high-reward R&D with a focus on developing pilots of commercializable ideas and pursuing commercialization—with

commercialization as the ultimate indicator of program success. Small, short-term grants to explore the technical merit of ideas could be followed by larger awards to evaluate commercialization potential.

The government plans to expand the SPREAD program in three ways. First, it will incorporate appropriate features from successful international programs, such as the U.S. Small Business Innovation Research program or the Canadian Industrial Research Assistance Program to spur ESTD of individual enterprises (see box 2.3). Second, it will provide additional matching grants for collaborations between private firms and universities or research institutes (see the section on commercialization, below). Finally, the government will provide additional grants to spur ESTD through formal sector initiatives that address the needs of poor people and through initiatives by poorer grassroots enterprises (see chapter 4).

The government also should consider developing a national policy and action plan to more effectively use public procurement as a policy instrument to promote innovation. India's space program through the Indian Space Research Organization has used public procurement in a productive way.¹² More broadly, public procurement can contribute to the growth and the creation of markets for innovative goods and services in the private sector. International experience suggests that central procuring agencies might be a way to overcome attitudes hampering

Box 2.3 International Programs to Stimulate Early-Stage Technology Development

Small Business Innovation Research (SBIR) program. The U.S. SBIR program provides grants to small businesses (fewer than 500 employees) to develop commercializable technology. A total of 11 federal departments and agencies are required to reserve 2.5 percent of their extramural R&D funds for the grants. These agencies designate R&D topics and solicit proposals. The businesses must also find funding in the private sector or other non-SBIR federal funding. There are three phases to the award process.

- Phase I is the start-up phase. Awards of up to \$100,000 are given for about six months of support to explore the technical merit of an idea or technology.
- Phase II awards of up to \$750,000, for as long as two years, expand on phase I results. During this time, the R&D is performed and the developer evaluates commercialization potential. Only phase I award winners are considered for phase II.
- Phase III is when phase II innovation moves from the laboratory into the marketplace. SBIR funds do not support this phase.

(continued)

Box 2.3 continued

The SBIR program has experienced explosive growth since its inception in 1983. In that first year, the program made 686 phase I awards totaling \$44.5 million to small high-technology firms. In fiscal 2004, the program issued 4,638 phase I awards and 2,013 phase II awards worth \$1.87 billion. Case studies of 44 projects have found that social rates of return average 84 percent under SBIR-funded projects, compared with 25 percent for projects without SBIR funding. A major objective of the SBIR program is to produce new high-technology products and services from federal R&D. In the program's early years, it was believed that very little federal R&D would result in the spin-off of commercialized products and services. However, the program has produced a stream of innovations, far exceeding early expectations. It is now estimated that nearly 40 percent of phase II projects will result in a commercialized product or service. These innovations cover the entire high-technology spectrum. For more on the program, including statistics, see <http://www.sba.gov/sbir/indexsbir-sttr.html>. For more information on the program's guidelines, see <http://www.sba.gov/sbir/SBIR-PolicyDirective.pdf>. For an evaluation of the Department of Defense Fast Track SBIR Initiative, see National Research Council (2000).

Industrial Research Assistance Program (IRAP). IRAP, sponsored by the Canadian National Research Council, provides a range of technical and business-oriented advisory services along with financial support to growth-oriented Canadian SMEs. The program is run by an extensive network of 260 professionals in 100 communities across the country. Working directly with its clients, IRAP supports innovative R&D and commercialization of new products and services. IRAP views SMEs as the strategic backbone of the Canadian economy and is committed to working with them while they realize their full potential and turn knowledge and innovation into strategic opportunities, jobs, and prosperity for all Canadians. The program funds feasibility studies, precompetitive R&D, adaptation, international sourcing, and hiring of young talent. It funds almost 3,000 projects a year, with support totaling C\$135 million (US\$122 million).

Small Business Technology Transfer (STTR) program. The U.S. STTR program is a competitive matching grant program that encourages commercialization of R&D from public labs, nonprofit research organizations, and nonprofit universities to the marketplace. The STTR program requires partnerships among these entities, while the SBIR program merely encourages them. The STTR program follows the same three phases as the SBIR program. Funding comes from the R&D budgets of the Departments of Defense, Energy, and Health and Human Services; the National Aeronautics and Space Administration; and the National Science Foundation. In 2001, the set-aside was increased from 0.15 percent to 0.30 percent. The STTR program began making awards in fiscal 1994, issuing 198 for about \$19 million to small high-technology firms that collaborated with nonprofit research institutions to undertake R&D. In fiscal 2004, the program awarded 614 phase I awards and 195 phase II awards totaling just over \$198 million.

Source: Authors.

the procurement of innovation, either by leading the movement toward innovation by a strong political mandate or by building up critical mass—and supported by a clear move away from traditional fixed procurement criteria, such as price, toward emphasizing life-cycle costs, outcomes, and innovative solutions for achieving them.¹³

Improving the Impact of Public R&D

Indigenous R&D spending as a share of GDP remains low and dominated by the public sector. This section explores what government should do to increase the impact of public R&D.

Organization and Selected Support Programs for the Public R&D System

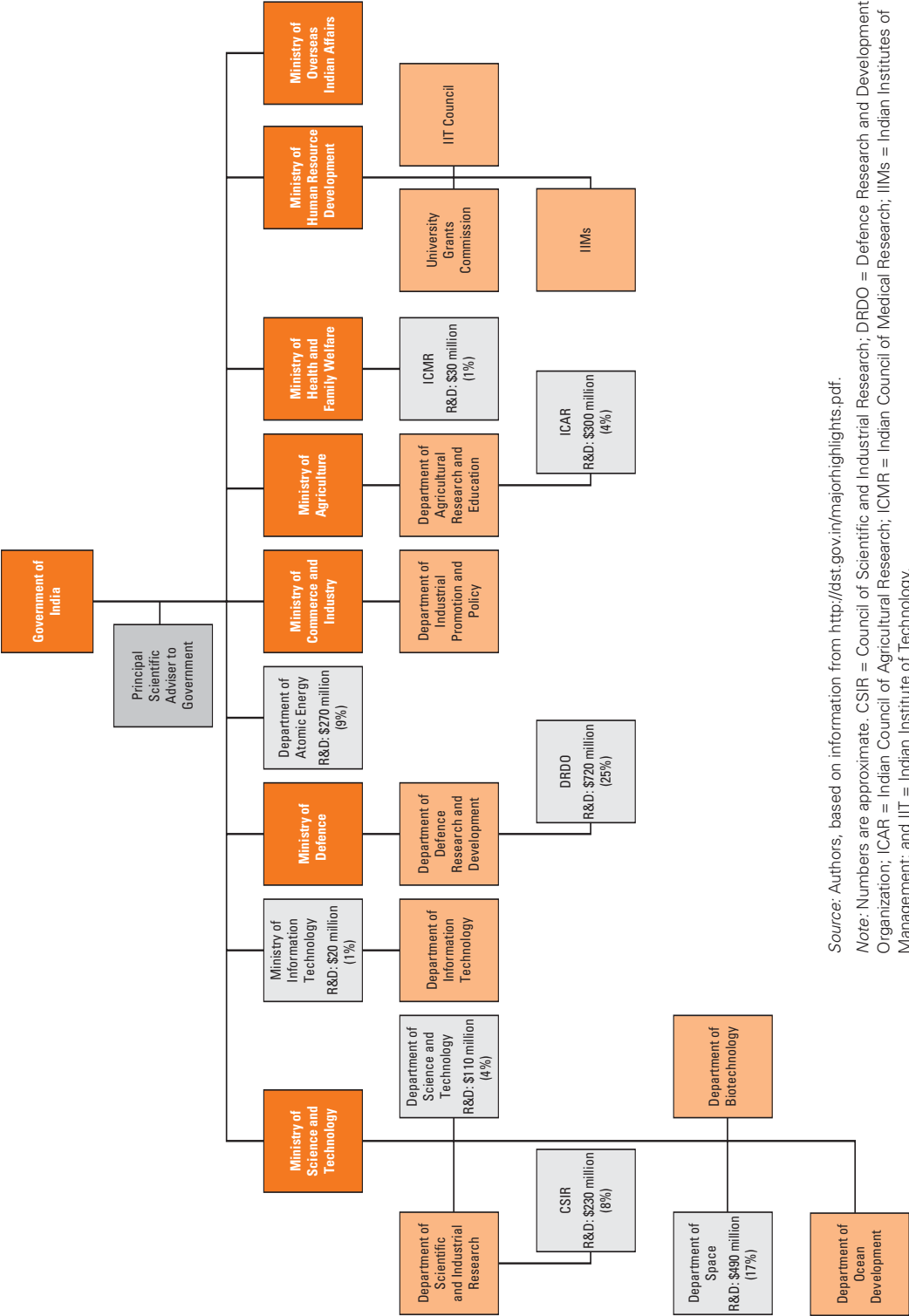
The public sector dominates domestic R&D. Figure 2.1 provides an overview of the main public institutions involved in R&D in India.¹⁴ The public sector (central and state) accounts for 70–80 percent of India's total R&D investment, equal to 0.8 percent of GDP. The bulk of that effort is mission-oriented R&D in defense, space, and energy by the Department of Defense Research and Development (25 percent), Department of Space Research (17 percent), and Department of Atomic Energy (9 percent), respectively. Less than 20 percent of public support for R&D is for civilian applications: 8 percent goes to the 38 labs that make up the Council of Scientific and Industrial Research (CSIR), 4 percent to Indian Council of Agricultural Research (ICAR) institutions, 4 percent to the applied research programs of the Department of Science and Technology (DST), and 1 percent to the Indian Council of Medical Research (ICMR).

The bulk of applied public research has been industrial research, which India has supported for more than 60 years through CSIR. With 38 laboratories and more than 5,000 researchers, CSIR is one of the world's largest collections of industrially oriented public research labs. It is India's main producer of scientific and technical publications and patents. Over the past 20 years it has gone through a major transformation—from producing technology for the domestic market to helping Indian industry become globally competitive and to being a global player itself. Many of the reforms it has made in its organization and management are relevant for other parts of the public R&D system (box 2.4).

Patents from CSIR labs include the following (Gupta 2006):

- A drug to alleviate vascular blockages (licensed to Cadila Pharma) that led to lower prices
- A partnership between National Chemical Labs and General Electric through which the latter has paid the former \$8.5 million and received six patents, including one to produce high-grade polycarbonates
- A water purification process licensed to industry

Figure 2.1 Key Public Institutions Involved in R&D and R&D Expenditures in India, 2003–04



Source: Authors, based on information from <http://dst.gov.in/majorhighlights.pdf>.
Note: Numbers are approximate. CSIR = Council of Scientific and Industrial Research; DRDO = Defence Research and Development Organization; ICAR = Indian Council of Agricultural Research; ICMR = Indian Council of Medical Research; IIMs = Indian Institutes of Management; and IIT = Indian Institute of Technology.

Box 2.4 CSIR: Restructuring from Technology Development for Self-Reliance to Internationally Competitive, Market-Driven R&D

The Council of Scientific and Industrial Research (CSIR) was set up in 1942, modeled after the U.K. Department of Scientific and Industrial Research. It predated most other specialized R&D institutes in India and had a wide range of functions, from promoting scientific research and establishing R&D institutions to collecting and disseminating data on research and industry. After India's independence in 1947, CSIR became an independent entity under the prime minister. In the first two decades after independence, it focused on building up an extensive R&D infrastructure, from metrology to R&D for a wide range of industries—with a focus on supporting emerging industry, especially SMEs.

The global energy shock of the early 1970s coincided with three years of consecutive drought in India. In the pursuit of Indian self-reliance, CSIR concentrated on reverse engineering products and process technology, primarily in pharmaceuticals, chemicals, glass, and other import-substituting industries, and in adding value to technologies using domestic resources such as high-ash coal, small-scale cement plants, and medicinal and aromatic plants.

The process of reform was initiated in 1986 by the Abid Hussain Committee report, and was given additional impetus when India shifted from an inward-oriented to a more outward- and market-driven development strategy as a result of the 1991 economic crisis. With the liberalization of trade and industrial policy, firms began facing more international competition. CSIR was criticized for being unwieldy and ineffective at transforming laboratory results to technologies for industrial production, and for spending too much effort “reinventing the wheel” by focusing on known processes. The demands of the crisis led to self-examination and radical change in CSIR's role—from emphasizing technological self-reliance to viewing R&D as a business and generating world-class industrial R&D. More emphasis was placed on outputs and performance, and on work that was relevant for productive sectors and that could earn income. Each laboratory became a corporate subsidiary, and rewards were introduced for meeting targets. Laboratories were given autonomy in operations based on how well they delivered on committed outputs and deliverables. In addition, there have been continuous efforts to streamline further to improve effectiveness and efficiency.

Although CSIR is still restructuring, the results to date have been quite impressive. They show the kind of impact that a change in the direction and incentive regime of even a very large public research system can have. Between 1997 and 2002, CSIR cut its laboratories from 40 to 38 and staff from 24,000 to 20,000. There was also a noticeable increase in its output. Technical and scientific publications in internationally recognized journals jumped from 1,576 in 1995 to 2,900 in 2005, and their average impact factor increased from 1.5 to 2.2. Patent filings in India rose from 264 in 1997–98 to 418 in 2004–05. Patent filings abroad quintupled from 94 in 1997–98 to 500 in 2004–05, and CSIR accounted for 50–60 percent of U.S. patents granted to Indian inventors. In addition, CSIR increased earnings from outside income from Rs 180 crore in 1995–96 to Rs 310 crore in 2005–06 (about \$75 million). Today it has 4,700 active scientists and technologists supported by 8,500 scientific and technical personnel. Its government grant budget has roughly doubled since 1997, and is now Rs 1,500 crore (\$365 million), so its earnings are about 20 percent of its grant budget.

Source: Based on Bhojwani (2006).

- A process for producing liquid fertilizer and other products from fresh seaweed that is promoting seaweed cultivation among poor farmers
- A process for biodiesel production
- A process for converting calcium carbonate-rich inorganic byproducts to industrial products, with benefits for environmental amelioration and job creation
- The development and patenting of several varieties of mint plants, which have made India a major player in the international mint market and created new jobs in agriculture
- Various medical patents licensed to Indian and foreign companies.

A number of public sector-driven research programs, such as those of the Technology Development and Transfer (TDT) program, would benefit from an increased focus on market-led commercialization. A key characteristic of these programs is that they do not require private enterprises to be the initiators of funding requests, so most requests come from national R&D organizations and their subsidiaries. Most of the programs are operated by government bodies, with insufficient private participation in their management and operations. Furthermore, most of the programs have not been subjected to independent evaluation and international benchmarking. The TDT is an initiative by DST to consolidate several programs, including the State Science and Technology Program (SSTP, known as State Councils), Technology Systems Program (which, among other things, aims to strengthen indigenous capability for research, development, design, and production of instruments, including sensor and medical instrumentation), and the Pharmaceuticals R&D Support Fund (PRDSF).

For any project under TDT to receive public funding support, industry must commit at least 10 percent of costs—a requirement that is in the right direction but insufficient. The SSTP (formerly known as the Scheme for Assistance for Development of State Science & Technology Councils) is the only central scheme focused on promoting science and technology in states. Implemented in 1981, the scheme supports State Councils in formulating and implementing science and technology activities, including demonstration projects. During 1998–2005, roughly 175 projects were supported, including micro hydroelectric projects in Arunachal Pradesh, Manipur, Nagaland, and Sikkim; reverse osmosis water treatment plants in Gujarat, Rajasthan, and Tamil Nadu; and low-cost sewage technology in Punjab. Although TDT programs have led to a number of technology development success stories in the areas of energy, water, waste management, and drug development, there has to be mass commercialization—crucial to meet the needs of the country as a whole.

With the New Millennium Indian Technology Leadership Initiative (NMITLI) fully launched only in 2003, it is early to expect market successes—though it has a number of impressive precommercialization accomplishments. Piloted in 2001 and fully launched in 2003 by CSIR, NMITLI is a prestigious, unique public-private partnership program designed to catalyze innovation-led development and achieve global leadership positions in a few high-risk technology niches. The program aims to

turn sound technological ideas into reality through systematic development of innovative projects. Since its inception, NMITLI has supported 42 projects involving more than 65 industry partners and 222 R&D institutions, with an estimated outlay of about Rs 300 crore (\$65 million). NMITLI's precommercialization successes include Biosuite (software for conducting diverse bioanalysis), a tuberculosis treatment breakthrough involving 1 industrial and 12 institutional partners, and a psoriasis treatment involving 2 institutional and 1 industrial partner. While impressive accomplishments, most have not had much market success—partly because a few projects have been slow to get to market and been beaten by competitors.

Assessment of the Public R&D System

Relative to India's economic size and the international context, the amount of public research is low. The effectiveness of public R&D spending is also low—as shown by the stronger record in scientific and technical publications than in patenting, and by the limited commercialization of technology generated in the public R&D system. Still, India has seen a dramatic increase in patent filings in recent years. Nearly 800 Indian companies submitted applications to the World Intellectual Property Office in 2004, more than twice the number in 2000. Similarly, the cost per patent application and per scientific and technical publication in India is among the lowest relative to comparator (BRICKM) countries (Brazil, Russia, China, Korea, and Mexico) (Gupta 2006). Hence, India needs to increase R&D spending and boost efficiency and effectiveness. Key issues that need to be addressed include the following:

- *Fragmentation.* The public R&D system is extremely fragmented. A plethora of central government structures, organizations, instruments, and programs has emerged in response to specific needs and challenges. There has to be a deliberate effort to develop a national governance structure for innovation. This will avoid an overlapping and exceedingly complex structure that has undermined the system's effectiveness.
- *Bureaucracy.* Processes are slow, bureaucratic, and hierarchical. An innovation system needs to function and perform much faster and be responsive. Even the more application-oriented parts of the system—such as CSIR, ICAR, and ICMR—would benefit from a more pragmatic, real-time orientation.
- *Lack of coordination.* Little advantage is taken of potential synergies across programs even within ministries, and much less across ministries.
- *A focus on financial inputs rather than outcomes and impacts.* With few exceptions, the focus is on getting more funds for each program. More attention needs to be paid to monitoring and evaluation of effectiveness and systematic international benchmarking of programs.
- *A narrow definition of innovation.* R&D is given more emphasis over innovation. R&D may be the easiest and most visible indicator for pursuing innovation, but

it does not constitute innovation. In fact, this approach may discourage other, more cost-effective innovation—such as adopting and adapting existing technology from other domestic locations or abroad.

- *Too much focus on frontier technologies.* Public R&D has focused on frontier and priority sector innovations, though some efforts have been made to prioritize traditional knowledge and rural innovations. However, these latter efforts seem to have the quality and implementation rigor of add-ons. Stronger efforts are needed to harness formal innovation efforts for the needs of the informal sector and the poor (see chapter 4).
- *Insufficient focus on more commercial and applied areas of public goods such as industry, agriculture, and health.* India should consider putting more effort into more economically relevant public goods such as precompetitive research, and socially relevant innovations such as preventive medicine, public health, technologies for sustainable livelihoods for the poor, and environmentally friendly technologies.
- *Focused effort to orient public research to the needs of the economy.* Most public research labs need to have clearer mission statements or clearly monitorable objectives. Although the goals of research institutes in different areas and the conduct of different functions (basic versus applied research) will differ in how they are organized and against what criteria they are evaluated, in general there is not a clear orientation toward results or accountability.
- *Insufficient effort to increase interaction among public research institutes, universities, and the productive sector.* Public research institutes should not work in isolation—from other public research institutes, universities, and the productive sector. Global experience shows that greater interaction among these three main research performers improves the quality and relevance of research.

Recommendations

To improve the impact of public R&D, India should consider allocating more resources to productive and social applications. Reforms should be considered in three areas:

1. *Increasing resources for civilian research.* Although CSIR has been restructured to focus on more market-driven R&D, and further restructuring is under way, the public R&D system as a whole would benefit from an independent evaluation and restructuring across the three main central civilian research agency networks (CSIR, ICAR, ICMR), to take greater advantage of cross-institution synergies and increase their focus on commercialization—with a systemwide action plan to consolidate and transfer some R&D labs to the private sector so that their work programs are fully market-driven. A relevant political economy consideration is that in most countries, it is quite difficult to cut budgets

and programs. A possible strategy would be to gradually reduce budget allocations to poorly performing institutions and programs by making them compete for at least part of their usual allocations. In addition, most growth in public funding should be offered competitively to programs and institutions that meet prespecified criteria and win the funds in peer-reviewed competitions. Similarly, all matching funding to private research groups should be made available only through competitive allocations.

2. *Increasing support for R&D in universities.* Basic science and engineering research of a public goods character can probably be better supported through competitive research grants for university research and public labs, along the lines of the U.S. National Science Foundation (as contemplated in the planned National Science and Engineering Foundation).
3. *Strengthening support for R&D of high-risk technologies through NMITLI.* CSIR plans an independent evaluation of the NMITLI program using international benchmarking, to assess options for programmatic strengthening—including adoption of the entrepreneurial program management and agile decision making exhibited by the U.S. Defense Advanced Research Projects Agency (DARPA) and the industry-driven, cost-sharing approach of the U.S. Advanced Technology Program (ATP) (see box 2.5). Current plans for scaling up NMITLI include providing support for pre- and post-NMITLI activities, opening the program

Box 2.5 International Examples of Supporting High-Risk Technologies: DARPA and ATP

Defense Advanced Research Projects Agency (DARPA)

DARPA is the central R&D organization for the U.S. Department of Defense. It manages and directs selected basic and applied R&D projects for the department, and pursues R&D where risks and payoffs are both very high and success may provide dramatic advances for traditional military roles and missions. DARPA was established in 1958 in response to the challenge posed to the United States by the launch of the Soviet Sputnik in 1957. Its explicit objective was to keep the United States ahead of its enemies by developing superior, disruptive military technology.

DARPA is reputed to have about 240 staff and an annual budget of \$3.2 billion. In addition to significant military technology breakthroughs such as space programs and ballistic missile defense (1960s), stealth aircraft (1970s), and unmanned aerial vehicles (1980s), DARPA has been credited with developing many technologies that have had a major impact on the technological underpinnings of current society—such as the computer network that eventually developed into the Internet and important advances in materials, information technology, and biosciences. DARPA programs seek to go beyond the R&D being conducted by the U.S. armed forces, exploit more fundamental research and radical new concepts, and bridge the gap between research and use.

(continued)

Box 2.5 continued

Some key elements of DARPA's management strategy are to have limited overhead and no laboratories or research facilities, to minimize institutional interests that might distract the agency from its imperative for innovation. It brings in experts—entrepreneurial program managers—empowers and protects them from red tape, and quickly makes decisions about starting, continuing, or stopping research projects. It typically hires program managers for four to six years. It seeks to create synergies by hiring experts with similar interests. In most of its programs DARPA invests 98 percent of its funds at external organizations, primarily universities and industry. This approach leads to the development of new capabilities in industry and reduces the risk of the underlying technology to the point where companies are sufficiently confident in its capability, value, and technical maturity to try to commercialize it. For more information on DARPA, see <http://www.darpa.mil/body/mission.html>.

Advanced Technology Program (ATP)

The ATP, under the National Institute of Standards and Technology (NIST), was created as part of the Omnibus Trade and Competitiveness Act of 1988. Its objective is to benefit the U.S. economy by conducting cost-sharing research with industry to foster new, innovative technologies. ATP projects are proposed not by the U.S. government but by industry. The ATP project selection process includes both government and private experts. Projects are selected based on technical and economic merit, and demonstrated need for ATP funding. The ATP requires that projects have well-defined goals and sunset provisions. The ATP does not fund product development. It only funds R&D to develop high-risk technologies to the point where it is feasible for companies to begin product development. It has included program evaluation from its outset.

The ATP can fund up to \$2 million a year in direct project costs for up to three years for individual companies and up to half of project costs for up to five years for joint ventures. It does not limit the size of the companies involved. It encourages R&D partnerships and consortia with academia and research institutes. Companies control the intellectual property rights to the results of their research. The overall performance of ATP-funded projects has been positive. Benefit-cost studies for 40 projects estimated more than \$18 billion in expected present value social benefits—far more than the \$2.3 billion spent on the projects through September 2004. It is also alleged that 40 percent of the projects would not have been undertaken, that 40 percent would have proceeded much more slowly, and that the programs foster high rates of collaboration among firms and between them and universities and research institutes. For more information, see <http://www.atp.nist.gov/index.html>. For more on the evaluation methodology, see Ruegg and Feller (2003) and National Research Council (2001).

Source: Authors.

up to international collaboration, and providing grants to both research institutions and private enterprises, with sharing of royalties. It would also be desirable to consider providing research management training to NMITLI staff to help them better identify and manage promising Indian technology leadership opportunities.

Strengthening Commercialization of Knowledge

India's efforts to move ideas from laboratories to markets have tremendous potential. To date, however, much of the knowledge that is created—especially by the public sector—is not commercialized. This final section explores the role of public policy in strengthening the commercialization of knowledge.

Assessment of the Environment Spurring Commercialization

India's private sector has little interaction with public sector R&D. In 1987, the Ministry of Science and Technology's DSIR introduced the National R&D Awards Scheme to recognize the achievements of in-house R&D units. Since then 150 units have received the awards. A study of 88 of these units found that less than 15 percent had interacted with or used the services of public sector R&D units in developing the award-winning technologies (Bhojwani 2006).

Government entities responsible for commercialization—particularly the Technology Development Board (TDB) and National Research Development Corporation (NRDC)—have had limited success in meeting their mandates. The government created the TDB in 1996 to facilitate the commercialization of indigenous technology. Between 2001 and 2006, the TDB supported more than 100 entrepreneurial ventures. One of TDB's initiatives is to provide seed funding to technology-based companies. Its assistance is about 80 percent loans, 13 percent grants, 5 percent participation in the India Technology Venture Unit Scheme, and just 1 percent equity.

The TDB recently collaborated with two private equity firms to invest equity in start-ups: Andhra Pradesh Industrial Development Corporation–Venture Capital Fund, VCF, contributing Rs 30 crore (\$7.3 million) to the Biotechnology Venture Fund; and UTI Ventures, contributing Rs 75 crore (\$18.3 million) to UTI Ascent India Fund. Since its inception the TDB has signed 141 agreements—137 with commercial enterprises and 4 with other agencies, committing Rs 663 crore (\$162 million) and disbursing Rs 526 crore (\$129 million) as of March 31, 2005, with total project costs of \$454 million. Its main beneficiaries have been health and medical, air and road transport, and engineering firms. However, given the constraints typically accompanying a government-run program (such as risk aversion), the TDB has mostly granted assistance in the form of unsecured debt. Such debt does not have an upside and offers no potential for leveraging and cross-subsidizing the pool of debt to address a larger market. There is a need to look into the operational and organizational systems and the intended role TDB is supposed to play in the emerging economic environment, keeping in view the experience gained over the last decade.

Although the NRDC is a profitable public enterprise, it has not been successful as measured by the low overall commercialization of publicly supported R&D. The NRDC, established under DSIR, is the only public enterprise wholly dedicated to transferring technologies from R&D labs to industry. It is mandated to commercialize technologies developed with government support, upgrade laboratory know-how, set up pilot plants, and provide risk finance to development projects. The

NRDC has executed projects worth \$6.7 million and is negotiating contracts with several countries in Southeast Asia, Europe, Latin America, and Africa to execute projects worth about \$24 million. The NRDC has licensed 2,000 technologies for commercial application. Of these, 1,000 are in production, with an annual turnover of Rs 1,200 crore (\$293 million). These results are much too low relative to the potential of commercialization of publicly supported R&D. Although the NRDC continued to earn profits in 2004–05,¹⁵ its systems are too oriented to expenditure management and not sufficiently oriented to risk management.

A lack of strong incentives inhibits both a stronger orientation toward applied research in public institutes and the commercialization of technology created in the public sector. Although no law or regulation prohibits a commercial orientation, there is also no strong support for it. A significant event with respect to the commercialization of innovations that originated in U.S. academia was the passage of the Bayh-Dole Act of 1980. This act allowed U.S. universities to file for patents on any research undertaken using federal, state, or local government money. This encouraged professors and students to pursue applied research, to develop intellectual property, and even to start their own companies or find other means of commercializing intellectual property (such as licensing it to interested companies). Today, most U.S. research universities have well-developed licensing programs. Many have technology transfer offices that support university researchers in patenting and licensing technologies with commercial potential. In 2002, U.S. universities filed 7,750 new patent applications, and about 3,700 patents were approved (Evalueserve 2006). Other national IPR systems have also experimented with mechanisms designed to increase incentives for innovators laboring outside the confines of the large corporate environments responsible for most patent applications. Australia, for example, introduced an “innovation patent” system in 2001 to provide simple, inexpensive protection for inventions deemed insufficiently inventive to meet the threshold required for standard patents. Most such experiments are too recent to have generated meaningful data capable of assessing the extent to which they have achieved their objectives, but India should leverage the inquiries and recommendations leading to such experiments when considering their propriety in the Indian context.¹⁶

A modern regime for IPR is critical to promoting innovation and facilitating technology commercialization. Intellectual property rights are an important incentive for encouraging greater innovative effort. This is becoming increasingly important now that India has critical mass and greater capability for creating cutting-edge knowledge. This is also demonstrated by the recent significant increase in foreign investment in R&D centers—in contrast to their traditional concerns about the adequacy of intellectual property (IP) investment to protect their knowledge. However, India must protect its knowledge dissemination interests at the lowest possible costs, especially in areas of public concern such as health, and defend its interests in new technologies not yet fully regulated by international agreements.

Although India has a modern legal framework for IPR, institutions that handle IPR issues need to be strengthened. India’s accession to the World Trade Organization (WTO) in 1995—and specifically its signing of the WTO’s Agreement on

Trade-Related Aspects of Intellectual Property Rights (TRIPS)—obligated it to harmonize many aspects of its patent system with standards prevalent in the developed world. In 2005, India introduced amendments that brought its patent laws into full compliance with TRIPS. These amendments have had dramatic effects. India has done the following:

- Extended the life of its patents from 5–14 years to a TRIPS-mandated 20 years.
- Started granting product patents on a range of pharmaceutical and therapeutic innovations, including exclusive marketing rights on drugs. Previously only process patents and weak rights were available.
- Preserved its right to turn normally exclusive patent rights into compulsory licenses—but accepted TRIPS limitations in cases where such actions are required.
- Introduced limited patentability for software. The new law retains existing patents on stand-alone computer programs, mathematics, algorithms, and business methods. But for the first time, it permits patents on applied software or software embedded in, or combined with, hardware.

The recent amendments also allowed India to avail itself of TRIPS' flexible margins. India's patent laws now incorporate various provisions to protect public health from capricious exercises of patent rights on important drugs; require patentees to disclose the sources of the knowledge underpinning their applications (pursuant to the Convention on Biodiversity), although not necessarily all prior art; and allow both pre- and postgrant challenges to patents.

The government should consider further legal strengthening for IT, software, pharmaceuticals, and chemicals. Although the 2005 amendments to its patent laws maintained the prohibition on patenting computer programs, mathematics, and business methods, they expanded the scope of patentability to include software applied to specific industrial problems and software incorporated with hardware as part of a single innovation. These changes are part of a global debate about the best ways to protect software within modern IP systems. Around the world, all IPR protecting software remain controversial. The lack of international norms on software IPR means that India retains considerable flexibility in tailoring its system to its needs. Simultaneously, the country can monitor both international developments in this area and potential changes that its domestic IT industry may undergo now that some of its innovations are patentable.

Unlike software, where India has made its statutory choices and must now monitor them as they unfold, its treatment of pharmaceutical and chemical patents remains incomplete. Three issues are outstanding. Would it be compatible with TRIPS to limit pharmaceutical patents to new chemical entities, rather than to all advances in pharmaceuticals? Would it be compatible with TRIPS to exclude microorganisms from patenting? And can the government share data—which it obtained from branded chemical companies seeking regulatory clearance to sell their products—with generic competitors seeking to develop products to launch upon expiration of applicable patents? On these issues the government will have to decide,

first, which policies best serve India's needs; second, whether these policies are consistent with India's international obligations; and third, regardless of whether they are inconsistent with those obligations, whether they confer enough benefits on India to warrant adopting them.¹⁷ In December 2006, a government-appointed panel of experts on patent issues, headed by Dr. Mashelkar, reported its conclusions with respect to the first two issues: rules limiting patentability solely to new chemical entities or excluding microorganisms from patenting would violate India's obligations under TRIPS (Mashelkar 2006). The government must now decide how to incorporate this advice into law.

The main challenge for India's IPR system is its implementation. India has already taken significant steps to modernize and professionalize its Patent Office. The government needs to complete this process. The program could include the following:

- *Modernizing the IPR infrastructure* with expanded physical facilities, modernized process and data collection and dissemination, online application filing and processing, better search and examination, and increased staff training and skills development. The support should include upgrading Indian Patent Offices as well as the Indian Patent Training Institute (located in Nagpur, Maharashtra).
- *Stimulating patenting and patent exploitation among individual inventors, SMEs, R&D labs, and universities.* India could consider reducing domestic filing fees for individuals and SMEs by subsidizing them on a needs basis. It could also consider government-sponsored or -subsidized loans and clinics to facilitate the filing of patent applications abroad. This could be a focus of expanded support to the Patent Facilitation Center of the Technology Information Forecasting and Assessment Council (TIFAC).¹⁸ In addition, the center or a new patent management corporation (see below), operated as a public-private partnership, should provide practical strategic and down-to-earth IP advice to firms, especially SMEs and grassroots innovators, in optimizing their patent strategies for innovations. This would include analyses of patenting benefits relative to expenses as well as suggestions on timing and location of patent filings, alternatives to patenting, and so on. They could help figure out which legal firm or person is the right one for the technology and sometimes serve as the initial interface with the lawyer. Finally, the government needs to support the development of domestic IPR capability in the legal and consulting professions by supporting training institutions, training fellowships, or both.
- *Creating a court of appeals for IPR*, as in the United States, as a longer-term consideration as awareness about IPR and the number of patent cases grows.

To deal with complex IPR issues as technology advances and India's industries and innovation system evolve, the government should set up an independent IPR policy think tank. Expert advice is needed on how to deal with new country-strategic IPR issues as they arise. The think tank's primary job should be to ensure that all government decisions about its IP policy conform to the needs of Indian society. To do so, the think tank should get input from leading Indian researchers, businesspeople,

policy makers, and lawyers to study what is in India's best interests. The think tank should also work with researchers in other countries, because decisions on these issues will have global repercussions once put into international law.

There is insufficient mobility of researchers between universities, public research labs, and enterprises. Most Indian PhDs in science work in public research institutes or universities. Few work in private industry. It is rare for researchers from the private sector to work at universities or public research labs, and vice versa. In addition, there is little exchange between Indian and foreign researchers. Public sector researchers rarely consider the potential for commercializing their innovations, particularly in ways capable of generating the revenues necessary to sustain a private venture. India's public sector laboratories and universities need to expand their consideration of these issues.

India would benefit from increased spin-offs from universities or public research centers to create new high-technology companies. Unlike in the United States, where many researchers at universities or public research labs leave to set up new high-technology companies, such spin-offs are not common in India. This is in great contrast to China, where more than 2,000 high-technology companies have been spun off from universities and public R&D centers. Some of these, such as the computer maker Lenovo, have gone on to become among the largest companies in the Chinese stock market.

Goals for science and technology parks and technology incubators are to promote technology commercialization, transfer, and diffusion—fostering links between universities, R&D labs, and industry and promoting the formation and growth of knowledge-based companies. The rationale for science and technology parks is that there are economies of scale and agglomeration in providing common infrastructure facilities (such as transport, power, information and communication technology connectivity, office and production space, and waste treatment) and technical services (such as recruitment, training, mentoring, financing, networking, and legal and IPR counseling) and in locating near universities and research institutes, to build bridges between the scientific and business communities. One of the best examples of a science and technology park is the Hsinchu Science Park in Taiwan, China (box 2.6).

The rationale for technology incubators is to give business support to technopreneurs who may have a technology business idea but lack the know-how and access to facilities to make it a reality. Technology incubators typically have two basic features. First, they offer a nurturing environment for resident companies—providing assistance in forming a company, training and mentoring, management, business planning and market analysis, and technical and legal assistance; and facilitating access to finance, networking, IPR-related assistance, equipment and infrastructure facilities of the host institution, and other shared services such as fax machines, conference rooms, and libraries. Second, they are home to 20–30 resident companies, which are generally graduated out after two to three years.

India needs to build on its experience with science and technology parks and technology incubators. In 1985 the government—through the National Science and

Box 2.6 Hsinchu Science Park

The Hsinchu Science Park is a showcase of success for Taiwan (China). Some 40 percent of the firms established in this government-promoted park—which currently accommodates 3,000 expatriates—were begun by entrepreneurs from the United States. The Hsinchu park has benefited from the high quality of education in Taiwan. The venture capital environment has also worked in its favor. Taiwan has benefited from close ties with Silicon Valley, with a transnational community of Taiwanese venture capitalists fostering a two-way flow of capital, skills, and information. There is also an emerging trend of grouping Taiwanese and Indian high-technology talent in Silicon Valley. Taiwan's government has been particularly successful in promoting its hardware industry through tax incentives, low tariff barriers, cheap credit, good infrastructure, and establishment of research institutes.

Source: Authors.

Technology Entrepreneurship Development Board (NSTEDB)—initiated the establishment of Science and Technology Entrepreneur Parks (STEPs) linked to academic and public R&D institutions. These STEP, 17 total, have focused on the information technology industry and have been extremely successful in promoting the growth of India's software industry. In 2000, the NSTEDB initiated a technology incubator program with hosts having a strong R&D orientation, focused on a few crucial areas of technology. The board provides grants for the establishment and operation of technology incubators for a fixed period, after which they are to become self-sustaining. In addition, CSIR has set up a strong Patent Cell, and all the Indian Institutes of Technology (IITs) have established Industrial Research and Consultancy Offices to promote, facilitate, and manage institute-industry interaction activities. Four of the institutes have also established campus-based incubators. CSIR's National Chemical Laboratory is creating an Innovation Centre to support small companies from the early-stage incubation of ideas to the manufacturing stage.

However, India's program for technology incubators has had mixed results. Although some incubators appear quite successful, such as those at IIT Bombay and IIT Chennai, many others are facing challenges. IIT Delhi, for instance, has focused on providing office space but lacks mentoring capabilities. At the same time, there are some excellent examples of public-private partnerships in these programs—such as the ICICI Knowledge Park in Hyderabad (box 2.7). India has 80 technology incubators and a few science and technology parks. In contrast, China has more than 700 technology incubators (and many science and technology parks), the United States about 1,000, Europe 1,000 (including 300 in Germany), and Korea about 300.

Furthermore, there are few common R&D and Service Centers in India. One of the few examples, the Andhra Pradesh Technology Development Center, is facing challenges and requires restructuring. The United States is by far the most successful

Box 2.7 Collaborative Public-Private Partnerships: ICICI Knowledge Park and the Center for Genomic Application

The ICICI Knowledge Park

Established in 2003, the park is an excellent example of a public-private partnership providing facilities for life sciences and pharmaceutical research. It is part of a dynamic biotech cluster, known as the Genome Valley, in and around Hyderabad. The physically disaggregated biotech cluster is loosely based on the Bio Valley concept in Europe. ICICI Knowledge Park, SP Biotech Park, Bharat Biotech, Shanta Biotech, and various academic institutions such as the Indian Institute of Chemical Technology, the Centre for Cellular and Molecular Biology, the University of Hyderabad, and the International Crops Research Institute for the Semi-Arid Tropics form important nodes of the cluster.

The park provides more than 77,000 square feet of modular, wet laboratory, ready-to-use blocks for life sciences research at competitive prices. A Virtual Information Center, set up with the help of DST, forms an information network connecting tenant companies to a host of research and academic institutions around the country. Besides providing shared infrastructure facilities for life sciences research, the park is planning to assist enterprise creation by leasing incubation laboratory facilities to up-and-coming enterprises. The park will also help firms prepare business plans, assess market opportunities, and solicit venture funds. In 2006 the park also envisaged creating a competitive seed fund for new life sciences-based enterprises and opening a public health laboratory for research on neglected diseases.

The Centre for Genomic Application (TCGA)

Opened in 2004, the center is a collaboration between CSIR's Institute of Genomics and Integrative Biology supported by DST, the Institute of Molecular Medicine, and the private sector. TCGA is the first public-private partnership providing life science services in India. With a staff of 37, it is India's largest co-share facility, with cutting-edge technological expertise in genomics and proteomics and providing services to more than 100 organizations. Besides providing high-quality services, TCGA has also started participating in research projects. Its mandate includes

- creating necessary infrastructure and work ambience, on par with international research facilities, to provide support to R&D institutions, universities, and industry, to contribute to the discovery of new molecular and predictive medicine;
- empowering a large number of small laboratories (in universities and R&D institutions) to take advantage of cutting-edge facilities, to make new discoveries in the post-genomic sequencing era; and
- catalyzing the genomic revolution in India's R&D sector to bring affordable health care benefits to the people of India.

TCGA is now setting up incubation facilities with the aim to "create a new generation of entrepreneur scientists as future biotechnology business leaders of India."

Source: Authors.

model of holistic entrepreneurship-driven technology enterprise creation. Its experience with the development of science and technology parks around the universities of MIT (Massachusetts Institute of Technology), Stanford, and Harvard has been quite successful, and the parks have created a large pool of internationally renowned technology companies. Similar structures have been created in the United Kingdom, where Microsoft worked with Cambridge University to create research facilities and provide venture financing for new software and networking technologies.

Recommendations

To strengthen commercialization of knowledge, India should foster increased collaboration between R&D institutes, universities, and private firms. Seven areas of reform follow:

1. *Strengthening incentives for commercialization of publicly funded R&D.* The U.S. Bayh-Dole Act of 1980 encouraged university professors and students to commercialize their intellectual property. India should consider strengthening incentives for commercialization of publicly funded R&D in India by passing similar legislation appropriate to the Indian context. While the situation in India today is different from that in the United States in 1980—there is no Indian law prohibiting patenting development and commercialization derived from using public research funds—there would still be a signaling benefit from clarifying India's legal framework along the lines of the CSIR–Patent Facilitation Center guidelines currently in force at some ministries. Any new law should promote the emergence of an entrepreneurial spirit on all campuses and research institutes, with freedom to negotiate flexible deals with partners in the private sector, and rewards flowing back to the labs and individuals who contributed to the revenues.
2. *Improving support infrastructure for India's IPR regime.* India's legal framework for IPR has been modernized. Still, outstanding IPR implementation issues remain. The drive to modernize the country's IPR implementation system is already under way. In addition, the government is expediting plans to upgrade the Indian Patent Office and expand support for individuals and organizations seeking to patent in India and abroad through an upgraded Patent Facilitation Center. Over the longer term, the government is considering creating a special court of appeals for IPR. Finally, to provide country-strategic policy advice on complex IPR-related issues such as technology advances and ensure that they are resolved in India's interest, the government is considering creating a policy-oriented think tank on outstanding IP issues.
3. *Supporting technology transfer offices and a patent management corporation.* Legislation should go further in requiring all government agencies issuing research grants to motivate universities, research institutes, and their individual researchers to seek and exploit patents and engage in technology transfer programs with industrial concerns. In this context, a patent management corporation, structured

as a public-private partnership and as a replacement and restructuring of NRDC, could play a useful role in managing patent portfolios from CSIR and other public labs and universities, and assist in their commercial exploitation—as well as provide strategic IP guidance to SMEs.

4. *Promoting greater mobility.* Mobility of personnel between public R&D labs, universities, and industry should be encouraged through competitive awards with generous stipends.
5. *Expanding science and technology parks and technology incubators.* Technology parks and incubators should be expanded with government support and private finance and management, based on international best practice—including the experiences of Israel, Taiwan (China), the United Kingdom, and the United States. Managing these parks and incubators is a specialized job and requires intensive capacity building, training, and apprenticeship for mentors and financiers. Spin-offs also should be encouraged from universities or public research labs to create new companies. Scientists should be allowed to start spin-offs while holding their current jobs. The public support program should focus on the following:
 - Creating a few high-quality science and technology parks near a cluster of research universities and public labs (such as Lucknow, Pune, Hyderabad, Bangalore, New Delhi, Vadodara, and Chandigarh) where companies would set up their R&D labs and help create synergies between the industry and scientists.
 - Expanding the technology incubator program to most public R&D labs, IITs, Indian Institutes of Management (IIMs), and research universities with adequate facilities, including proper capacity for strategic mentoring for such units following a professional approach and adequate nurturing of firms.
 - Expanding common research and service center programs like CSIR's TCGA—a novel public-private partnership approach creating an excellent research and service lab. All these activities should include a strong public-private partnership element.
 - Promoting a “Technology Spin-Off Fund” to spur formation of new companies from R&D generated in labs and universities. This should provide seed and working capital, as well as business mentoring for such units.
6. *Broadening SPREAD and creating an appropriate “fund of funds.”* The government must develop better policies and mechanisms to strengthen the interaction among private firms and the public and university research infrastructure. With regard to public grant support for ESTD, the success of SPREAD as the first formal program in India for encouraging collaboration between technology institutes and firms should be broadened based on international benchmarking—including the U.S. Small Business Technology Transfer program, a competitive matching grant program that requires collaborative commercialization (see box 2.3). The TDB, however, should possibly be restructured as a public-private

Box 2.8 The Israeli Binational Industrial Research and Development Program

The Israeli Binational Industrial Research and Development (BIRD) Program was established in 1977 as an equal partnership with the U.S. government. The BIRD Foundation was seeded with \$110 million to fund joint ventures between Israeli and U.S. firms. BIRD provides half of a company's R&D expenses, with equal amounts going to each partner. Its returns come from the royalties it charges on the companies' revenue. Although only 25 percent of funded projects have been successful, this is a satisfactory rate, even for private funds. The money that BIRD has earned on profitable projects has more than offset losses made by the rest, allowing the program to maintain the value of its endowment. BIRD approves about 40 new projects a year, with average funding of \$1.2 million over 12–15 months. To date, it has funded 500 such projects.

Source: Authors.

partnership, with government provision of leveraged returns for private investment in innovation in areas overlooked by the market through a “fund of funds” program. Government support is justified to seed the private venture capital industry by mitigating some of the risk in return for requiring venture capital funds to invest in certain priority activities. Such a program should provide investments (as minority share, with the private sector raising a majority of resources) in privately managed venture capital funds that focus on fostering early-stage companies (and angel investing) to commercialize R&D outputs and scale up technologies that help rural, poor, and informal entrepreneurs (see chapter 7).

7. *Setting up a Global Research and Industrial Partnership (GRIP) program.* Finally, to spur greater international collaboration, the government of India is planning to set up a GRIP program inspired by the successful Israel-U.S. Binational Industrial Research and Development (BIRD) Fund (box 2.8), to support advanced R&D and commercialization to be carried out jointly by Indian enterprises with those from other countries, such as Canada, Israel, Russia, or the United States.

Notes

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1. For a recent critical review of government intervention in such areas, see Pack and Saggi (2006), who, among others, argue that India's software industry has grown despite rather than because of the government. Although it is true that public support likely ratified private success rather than initiated it, support such as tax incentives (providing increased cash flow for organic and inorganic growth), state-level efforts to expand engineering education, containment of rates of telecom services, and modification of stringent labor laws to give greater flexibility in hiring and firing of workers (Yusuf, Nabeshima, and Perkins 2007) likely had a positive impact.

Furthermore, biotechnology and pharmaceutical research seem to have benefited more directly from government support. For a review of some key policy instruments to support commercial innovation, see World Bank (2006).

2. See Jaffe (2002) on how to build evaluation into the design of public research–support programs.
3. In 1991, the private sector invested very little in R&D. The little R&D done was dominated by state enterprises.
4. *Business World*, December 25, 2006.
5. See Evalueserve (2006) for a detailed breakdown of the loaded cost for typical R&D with and without laboratory infrastructure in the United States versus India. The bulk of the total cost and cost differential is accounted for by payroll costs.
6. Based on Evalueserve (2006) estimates, total private spending on R&D over the two years 2004 and 2005 amounted to \$6.75 billion, though no breakdown is available between MNCs, domestic firms, and high tech start-ups.
7. See Bowonder and others (2006) and TIFAC (2005).
8. For a review of the existing literature on this subject, and evidence consistent with positive productivity spillovers from contacts between foreign affiliates and their local suppliers in upstream sectors, see Javorcik (2004). These data from Lithuania indicate that such vertical spillovers are associated with projects with shared domestic and foreign ownership but not with fully owned foreign investment.
9. Similar concerns have arisen in Israel, where the benefits of the rapid growth of the high-tech sector have eluded the rest of the economy, giving rise to a “dual economy” and slow growth for the economy as a whole. See Trajtenberg (2005) who argues that the notion of spillovers should be reexamined in view of globalization, which makes the actual benefits depend on the relative intensity of inward versus outward flows.
10. Academic research cites “partial appropriability of returns” and “information asymmetry” as the most important reasons for underinvestment in R&D and making the rationale for public support to commercial R&D. For a summary of these constraints, see World Bank (2006). For a more detailed discussion, see De Ferranti and others (2003) and Baumol (2002).
11. SPREAD was launched in the early 1990s as a part of the \$200 million World Bank–supported Industrial Technology Development Project.
12. See Sankar (2003), who shows that the Indian Space Research Organization is internationally competitive in output and quality.
13. See in particular Fraunhofer Institute for Systems and Innovation Research (2006), which analyzes existing rules and current practices of public innovation procurement in 15 European Union member states, Australia, Canada, Norway, and the United States, and provides examples of good practices for concrete procurement activities.
14. Although there is also a science and technology structure at the state level, it is not very large and is not covered in this report.
15. During 2004–05 the NRDC earned a gross profit of Rs 12.6 lakh (\$30,000), with lump-sum premiums and royalties on the licensing of technologies to industry of Rs 326.2 lakh (\$795,000) being its main source of revenue.
16. See Australian Government, IP Australia, “The Innovation Patent,” http://www.ipaustralia.gov.au/patents/what_innovation.shtml.
17. India’s choices can have significant implications. The introduction of patents on incremental improvements, making microorganisms eligible for patent protection, and prohibitions on data sharing will all make India a more attractive venue for MNCs and biotech firms. Narrower concepts of patentability and weak data protection laws will serve the interests of low-cost drug producers. Thus, India’s policy decisions and eventual legislation in these areas can shape the development of India’s pharmaceutical industry, affecting the cost and availability of drugs to consumers, number and types of domestic research opportunities, number and types of drug manufacturing facilities that MNCs choose to locate in India, and consequent shape of employment throughout the sector.

18. TIFAC is an autonomous agency under the Department of Science and Technology. TIFAC works on technology forecasting, technology assessment, and technology information, and runs a patent facilitation center. As part of its functions, the patent facilitation center not only provides information on patents but also helps individuals and organizations patent in India and abroad.

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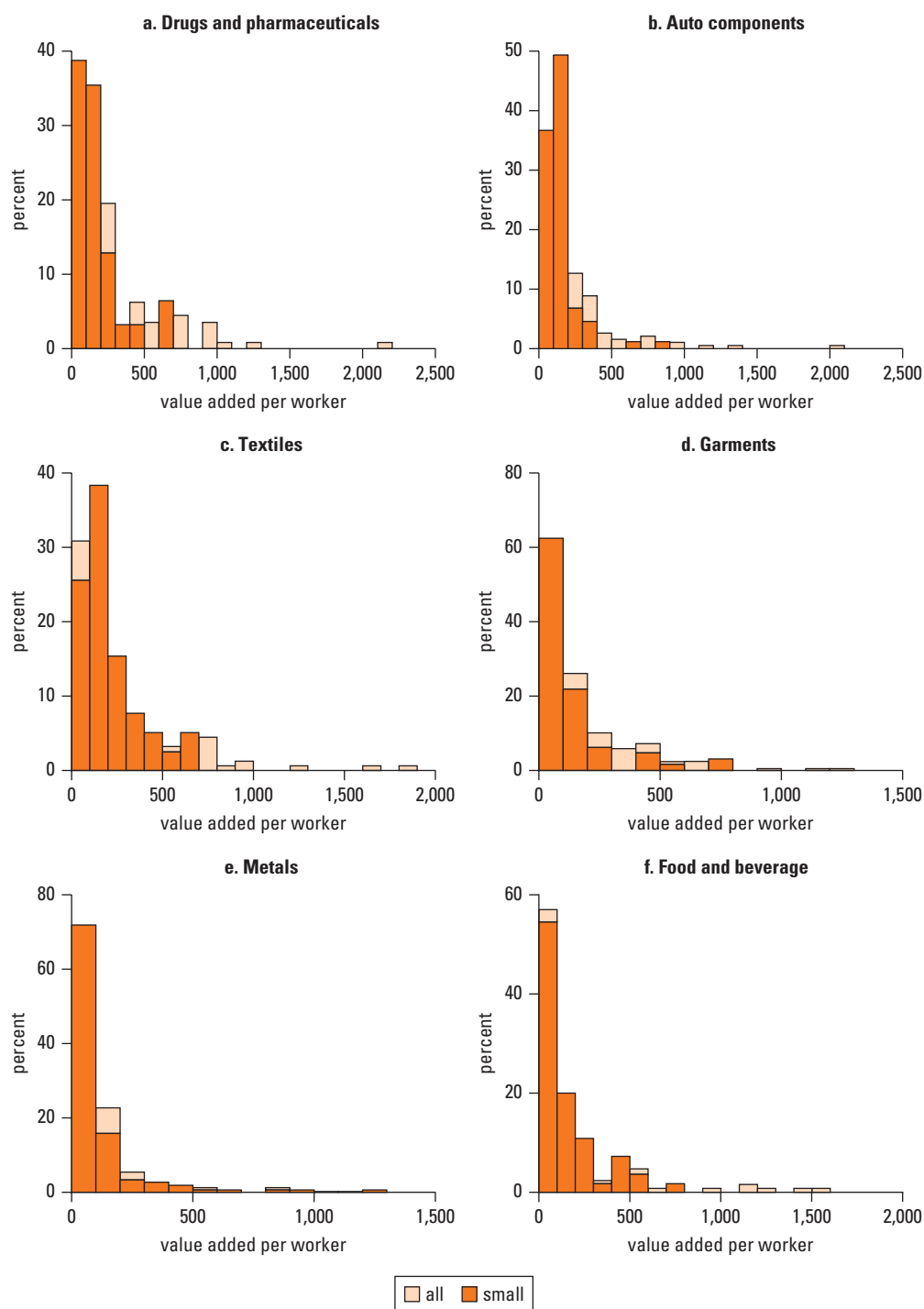
Diffusing and Absorbing Knowledge

Vinod K. Goel, Carl Dahlman, and Mark A. Dutz

India could reap enormous productivity benefits if local and global knowledge were better dispersed to and absorbed by domestic enterprises. Since independence, India has invested heavily in creating an excellent science and technology infrastructure by emphasizing public research and development (R&D) institutions. But it has not done as well in absorbing the knowledge generated by this domestic R&D system. Moreover, India has not taken sufficient advantage of the potential diffusion of internationally available knowledge and technology resources, as well as local knowledge. As a result, the absorption of knowledge by most Indian enterprises has been low. Most of the knowledge that India needs to boost productivity has already been discovered and is being used elsewhere in the country or the world, but remains underused by domestic enterprises. The potential productivity gains from better diffusion and absorption are particularly promising among small firms, especially those in the informal sector—given that they typically are the least connected to knowledge about prevailing best practices.¹ The low productivity of most Indian enterprises relative to top local performers indicates the large potential gains from making better use of existing knowledge.

The skewed distribution of enterprise productivity by sector—with small enterprises lagging far behind top local performers—reflects the low absorption of existing knowledge by most, and especially small, enterprises. Productivity is a good proxy for how well enterprises use existing knowledge. Firms with higher productivity presumably have absorbed or developed superior production and management technology. As discussed in chapter 1, productivity dispersion across formal enterprises in Indian manufacturing is wide relative to comparator countries. However, given India's stark economic heterogeneity—with formal sector employment accounting for no more than 11 percent of total employment—productivity dispersion across both formal and informal enterprises is likely much wider.

Figure 3.1 shows the frequency distributions of all formal enterprises and small formal enterprises according to value added per worker in six of the sectors covered by the World Bank's 2006 Enterprise Survey. These sectors represent a typical mix of the

Figure 3.1 Distribution of Value Added per Worker in India, by Sector and Company Size, 2004*(thousand rupees)*

84 Source: Compiled from India 2006 Enterprise Survey.

Note: US\$1 = Rs 45 in 2004. Rs 500,000 = \$11,100; Rs 1,000,000 = \$22,200.

Indian economy. Most of the firms—and, overwhelmingly, small ones—tend to clump at the low (left) end of value added per worker, while just a few firms operate near the national technological frontier (right) end. Based on a very conservative estimate, the “adjusted” technological frontier is about five times the means in the different sectors for all firms.² For small formal enterprises, average productivity is much lower—with the technological frontier about 6.3 times the means, and average productivity roughly 15 percent of top local performers. Smaller informal enterprises are likely to be even less productive. Thus, absorption needs appear greatest among small enterprises, especially among the roughly 90 percent of the workforce in the informal economy.

The skewed distribution of enterprise productivity also reflects the potentially large productivity and output increases from diffusion and absorption of local and global knowledge. The difference between the mean productivity of most firms and that of firms with the highest productivity shows the gains that could accrue to the economy if all firms were producing at the level of local best practice. This analysis implies that the output of the Indian economy could be as much as 4.8 times higher if enterprises were to absorb and use the knowledge that already exists in the economy.³ The absorptive needs of small enterprises and especially the informal part of the productive economy are even more significant, because their productivity is even lower. Additional efforts are needed to unleash the potential of informal enterprises (see chapter 4). Furthermore, the estimate of potential productivity gains is conservative, because it does not use the values of the most productive domestic firms operating in each sector. Moreover, local best practice is probably lower than global best practice. Thus, an economy such as India's could accrue even greater benefits if it were able to get all its firms to use techniques and knowledge closer to the global best practice of existing technology.

Spurring Enhanced Flows of Global Knowledge

The diffusion and absorption of market-relevant knowledge from abroad can occur through a number of complementary channels—including trade and foreign direct investment (FDI), direct trade of knowledge through technology licensing, and mobility of people (foreign education, foreign training of nationals, and knowledge flows driven by the diaspora, though only the last is addressed in this section).⁴ The findings of a recent analysis of cross-country Enterprise Survey data—based on a sample of almost 18,000 enterprises in 43 countries—help put this section's focus on trade and FDI in perspective. There is a statistically significant, robust, positive correlation between trade and FDI and absorption as defined in this volume—namely, the acquisition of existing technologies and their adaptation to local conditions. Firms that import are more likely to absorb knowledge than firms that use only domestic suppliers, while firms that export are more likely to absorb knowledge than firms that sell only to the domestic market. In addition, firms with minority foreign participation are more likely to absorb knowledge than are domestically owned firms (see Almeida and Fernandes 2006).

Trade, Foreign Direct Investment, and Increased Openness

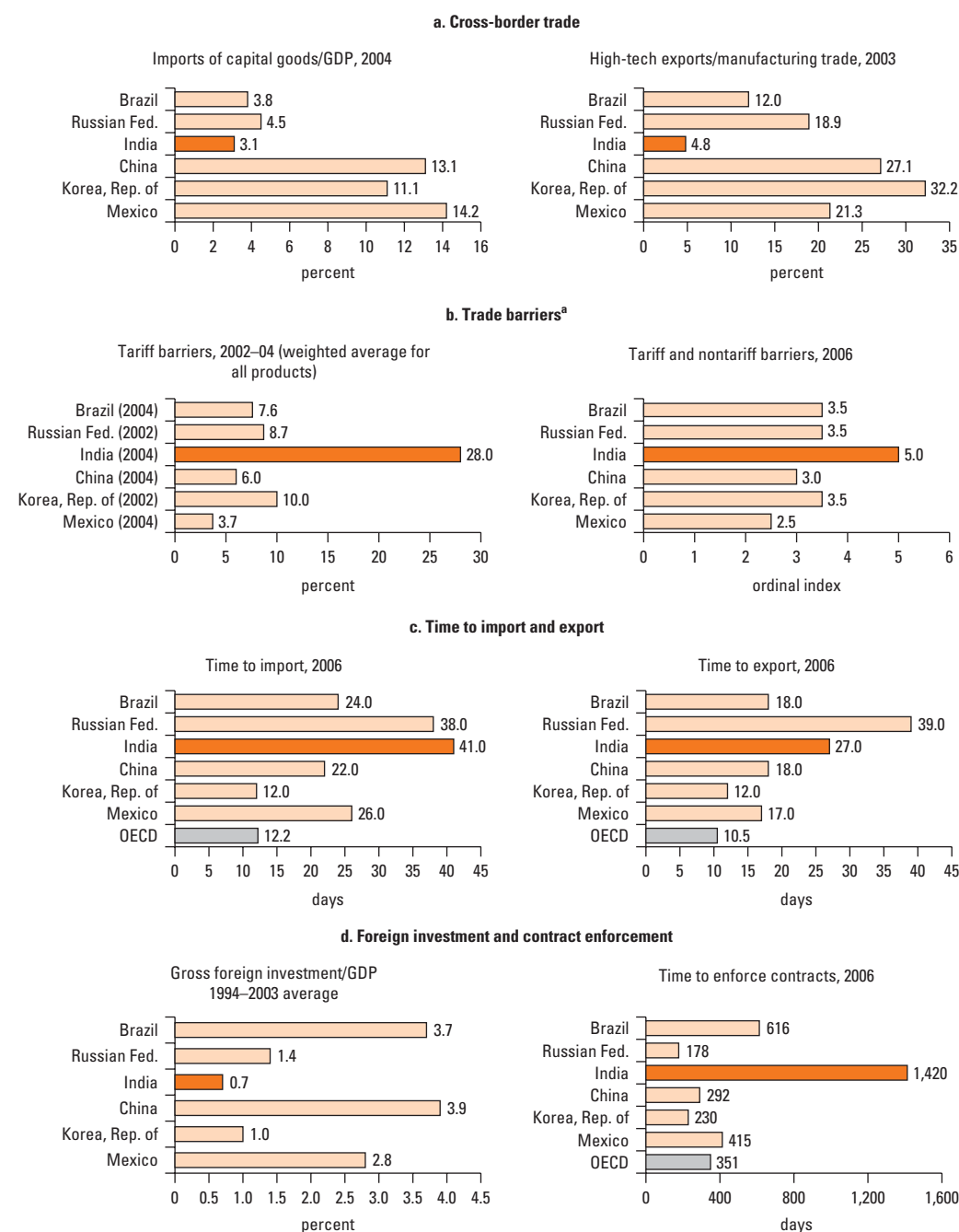
Trade and FDI openness are positively associated with innovation. Export orientation and foreign ownership are strongly and positively correlated in the India Enterprise Survey with developing new products as the output proxy for innovation. Export orientation is also positively associated with absorption of knowledge. The underlying transmission mechanisms are straightforward. Exposure to export markets both allows enterprises to learn about new technologies, new designs, and technical specifications through their interactions with foreign buyers, and provides an incentive—through enhanced rivalry—to upgrade technology more frequently. Foreign buyers also often provide technical assistance for the production of products that they want and that fit into their global supply chains.⁵

Similarly, importers can more easily upgrade technology by incorporating into their production processes state-of-the-art imported machinery, equipment, and other inputs that embody global knowledge. And to the extent that multinational corporations (MNCs) are endowed with more advanced technologies, they can transfer it to their subsidiaries through FDI. Recent research validates these benefits. For instance, in addition to the aforementioned research based on cross-country Enterprise Survey data, there is evidence that imports of intermediate inputs are positively correlated with enterprise and aggregate productivity, and that foreign knowledge embodied in imported inputs from countries with large R&D stocks has a positive effect on aggregate total factor productivity (TFP) in developing countries (see Kasahara and Rodriguez 2005; Lumenga-Neso, Olarreaga, and Schiff 2005; and Coe, Helpman, and Hoffmaister 1997).

On the export side, there is evidence of a learning-by-export effect (see Alvarez and Lopez 2005; Fernández and Isgut 2006). More broadly, there is cross-country evidence of a positive correlation between trade openness and the speed at which countries adopt new technologies and invest in R&D.⁶ On FDI, there is India-specific evidence that foreign firms are more likely than domestic firms to absorb new technologies (see Vishwasrao and Bosshardt 2001). In addition, there is evidence from the United Kingdom that firms more integrated with global markets are more likely to innovate, largely by making better use of available scientists and researchers (Criscuolo, Haskel, and Slaughter 2005).

Although Indian enterprises have benefited from the significant liberalization of the past 15 years, the country needs to further open trade for its enterprises to benefit as much as do comparator countries. Imports of capital goods are an important way to access global knowledge. As highlighted in chapter 1, enterprises of all sizes in the India Enterprise Survey indicate that capital goods were the most frequent source for absorbing new knowledge. However, as can be seen in figure 3.2a, imports of capital goods relative to GDP are lowest in India among comparator countries: Brazil, the Russian Federation, China, the Republic of Korea, and Mexico. High-technology exports as a share of total manufactured exports (figure 3.2b) are also significantly lower in India than in comparator countries—preventing a large number of Indian enterprises from interacting with and learning from global buyers of more sophisticated products.

Figure 3.2 Openness to Global Flows of Products and Capital in Various Countries



Source: World Bank 2006a, 2006b.

Note: OECD = Organisation for Economic Co-operation and Development.

a. For the graphs in this section, the lower the number, the more open the trade regime to imports and exports.

The low share of imports is closely related to trade barriers that, while having been ratcheted down from liberalization efforts, remain higher relative to comparator countries. Although India has been liberalizing its trade barriers, comparator countries have been liberalizing theirs even more—giving their enterprises a competitive advantage relative to Indian enterprises in accessing global knowledge. As shown in figure 3.2c, tariffs in India remain three to almost eight times higher than in comparator countries, while combined tariff and nontariff barriers (figure 3.2d) are significantly higher.

India's low openness to foreign trade is also driven by procedural requirements and implementation obstacles for exporting and importing (figures 3.2e and 3.2f). Trading across borders is slow and complex in India, which is ranked 139th of 175 countries in trade costs for exporting and importing a standardized cargo of goods. In particular, India needs to improve the time needed to comply with import procedures, which at 41 days (requiring 15 separate documents for imports) stands in stark contrast to 22 days in China, 24 in Brazil, 38 in Russia, and 12 on average in OECD countries (World Bank 2006a).

India also needs to build on its increasing openness to FDI so that enterprises can benefit as much as possible from FDI-related knowledge flows. Reforms since the mid-1980s, and particularly since 1991, have liberalized India's FDI regime, with most sectors falling under the automatic route of 100 percent FDI being allowed since 2000. In recent years most FDI has gone to electrical equipment (electronics and information technology), telecommunications, transport (automobiles and automotive components), chemicals and pharmaceuticals, and the service sector (financial, information technology, and business process outsourcing services), with most recently a focus on the R&D side of these sectors.

Despite these inflows, however, India continues to attract little FDI relative to comparator countries (figure 3.2g). Among the most prominent deterrents are infrastructure bottlenecks and cumbersome bureaucratic processes—including weak contract enforcement, which the government recognizes. Slow contract enforcement and inefficient courts are inimical to FDI because they create an uneven playing field and unpredictable environment that inhibit new entrants such as foreign investors and small businesses.⁷ Of the 10 areas of everyday business measured by the World Bank's annual *Doing Business* report, this is where India lags behind. It is among the four countries worldwide with the longest court delays, at 1,420 days to enforce a contract (figure 3.2h). This is at least partly linked to India's abnormally high number of related procedures, at 56—compared with 31 in Russia and China, and 22 on average in OECD countries.

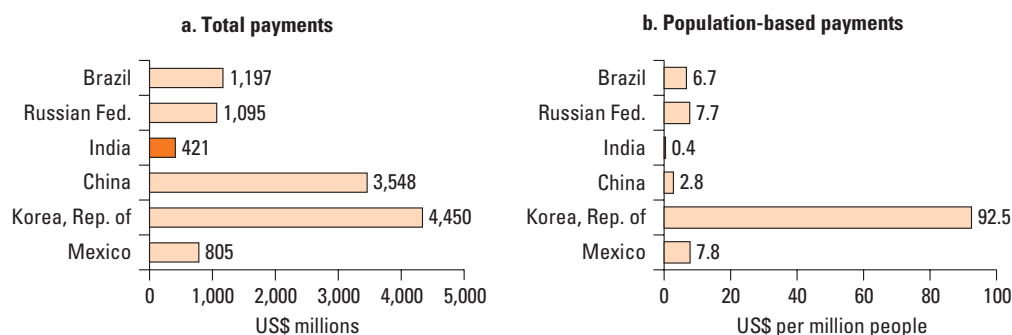
Further opening to trade and FDI would allow enterprises to gain more from global knowledge flows. A national innovation program and the opportunity for more Indian enterprises to benefit from global knowledge through greater openness in trade and FDI could provide a constructive context for further liberalization. A good starting point would be raising awareness of the economywide benefits from liberalization so far. Among the clearest of these benefits are the productivity

increases and jobs created in information technology (IT) and IT-enabled services and business process outsourcing, and in sectors that have benefited from the most openness to free trade and FDI. Recommendations for increased trade integration include expediting trade liberalization, with short-run priorities including extending duty drawbacks on imported inputs for exporters, strengthening export promotion for increased entry into global supply networks, and reducing procedural requirements for both exporting and importing. Recommendations for increased FDI include opening the remaining eligible sectors to such investment and setting up a one-stop shop for foreign investors. Key policy actions affecting both trade and FDI include simplifying related bureaucratic procedures, along with improving the functioning of the court system to create faster, more predictable contract enforcement.

Intellectual Property Flows and Technology Licensing

Technology licensing is a key channel of domestic and global knowledge absorption, yet it is underused in India. The direct trade of knowledge through technology licensing and other agreements is another way to acquire domestic and global knowledge. Based on the India Enterprise Survey, licensing and turnkey operations from domestic and international sources are an uncommon way of acquiring new technologies: only 2.7 percent of enterprises cite this as their most important channel for absorbing technology—with 1.7 percent relying on domestic sources and 1.0 percent relying on international sources. Across all the enterprises in the sample, only 8.3 percent (predominantly medium and especially larger enterprises) reported paying royalties or license fees to domestic or foreign companies. According to aggregate figures on royalty and license fee payments, India lags comparator countries in both absolute levels and relative terms, having spent only \$420 million in 2004—compared with \$3.5 billion in China and \$4.5 billion in Korea, translating to \$0.4 per million people relative to \$2.8 in China and \$92.5 in Korea (figure 3.3).

Figure 3.3 Openness to Global Flows of Intellectual Property in Various Countries, as Measured by Royalty and License Fee Payments, 2004



Source: World Bank 2006b.

Box 3.1 Technology Licensing Contracts***Nonautomatic (licensing through government channel)***

- Technology transfers where payments exceed the limits allowed under automatic approvals (see below)
- Technology collaborations in sectors not permitted under the automatic FDI route, cases involving reserved items by the Ministry of Small Scale Industries, and industrial licenses requiring government approval
- Payments for hiring foreign technicians; deputizing Indian technicians abroad; and testing indigenous raw materials, products, and indigenously developed technologies in foreign countries

The last category of payments is governed by separate Reserve Bank of India procedures and rules, and is not covered by the foreign technology collaboration approvals. Similarly, payments for imports of plant, machinery, and raw materials are not covered by foreign technology collaboration approvals.

Automatic approvals

- Lump-sum payments under \$2 million
- Royalty payments limited to 5 percent for domestic sales and 8 percent for exports—subject to a total payment of 8 percent on sales over a 10-year period
- The period for payment of royalties cannot exceed 7 years from the commencement of commercial production or 10 years from the date of agreement (whichever is earlier).

Source: Authors.

Although regulations on technology transfer have been liberalized significantly, scope remains for reducing barriers to technology licensing contracts. Foreign technology transfers and collaborations are licensed under two channels. The more restrictive channel is through the government, which requires approvals from authorities (box 3.1). There is scope for significant liberalization in these categories, shifting most to the automatic channel. The second channel, automatic approvals (box 3.1), is less restrictive. However, here again, there is scope for considerable liberalization by raising or removing some of these limits, subject to a facilitation rather than a control approach.

The government should consider strengthening support infrastructure for technology licensing, including through the possible creation of a global technology acquisition fund. Innovation—especially absorption but also creation—requires access to extant intellectual property (IP) from established firms. The low current

reliance by Indian enterprises on technology licensing, while partly due to weak local “innovate or perish” competition-type incentives, may also be due to market failures associated with information asymmetries, lack of knowledge of what technologies are available for licensing, where to tap them, how best to negotiate licensing terms, synergies from joint purchase and use of intellectual property, and the learning-by-doing nature of purchasing such technology rights or know-how.

As part of efforts to strengthen support infrastructure for technology licensing (including expansion of TIFAC’s patent facilitation program, discussed in chapter 2), the government may wish to explore establishing a public-private technology acquisition fund (with minority public share) to support the acquisition of patents and other rights to early-stage technologies and related know-how to fill gaps in India’s knowledge base. Such a fund could expedite commercialization of products where a particular piece of IP is missing locally but available internationally, reduce costs of acquiring the IP, and otherwise help create better (and cheaper) products for sale on global markets. By focusing on filling gaps in IP, this approach would not be picking winners but rather building on what IP is already locally known and available. By being structured as an autonomous public-private partnership, the fund would incite motivations parallel to those of the private sector. The fund would be a repository of both the skills to negotiate reasonable licensing and know-how acquisition terms from international holders of IP and the skills to devise appropriate payment structures for acquirers of it.⁸

Talent Flows and the Diaspora

India’s diaspora provides an important opportunity for further tapping into global knowledge flows. About 2 percent of India’s population (20 million people of Indian origin) lives abroad, earning roughly two-thirds of India’s GDP (Kuznetsov 2006). India’s high-tech diaspora is a unique, well-documented network that can take credit for some of India’s high-tech success. Indians are among the most successful immigrant communities in U.S. history, with more than 2 million currently living in the United States. Some 200,000 Indian-American families are headed by millionaires, and the median annual income of U.S. residents of Indian origin is \$60,093—much higher than the median U.S. income of \$38,885 (Ministry of External Affairs 2004). Two-thirds of foreign-born Indian-Americans have university degrees—three times the figure for Americans as a whole. More than 20 percent of U.S. information technology firms were started by Indian immigrants, and about 44 percent of these immigrants hold managerial or professional positions. The diaspora has been active in helping India through remittances, networks, access to knowledge and markets, and other resources. The old “brain drain” problem has become a great “brain gain” opportunity.

The diaspora has had a significant impact as investors and mentors, catalysts for policy change, and direct sources of returning talent. Indian expatriates have played a critical role in spurring India’s software and business process outsourcing boom.

These developments have led to a second crucial expatriate role, with Indian expatriates becoming senior executives at many major U.S. corporations—such as IBM, General Electric, Intel, Microsoft, Cisco, and American Express. In nearly every instance where these companies invested in or outsourced work to India, a well-placed expatriate executive crucially influenced the decision. In part, the individual's own success supported the emerging positive reputation of Indian engineers. And in part, the individual's direct experience with India gave that individual credibility in vouching that India's infrastructure and bureaucracy problems could be overcome.

In addition, some expatriates have returned to India for one to two years to supervise U.S. investments or outsourcing contracts, helping to train and manage to U.S. performance standards. Kanwal Rekhi, one of the founders of TiE (The IndUs Entrepreneurs, a global nonprofit network dedicated to advancing entrepreneurship), embarked on a well-publicized series of speeches and interviews in India in which he challenged the government and locals to pursue modernizing reforms. With the increasing FDI in India's IT and electronics industries, many Indian technology professionals have returned home. More than 30,000 technology professionals have returned to India since 2004 (Rai 2005). Their inducements include Western management practices and work cultures, liberal pay packages, and good career prospects, reinforced by a weak IT job market in the United States during 2001–04. Fresh Indian talent in many U.S. universities is also lured back to India. In 2005, of the 2,300 employees at General Electric's John F. Welch R&D Center in Bangalore, 700 were Indians who had returned in recent years. Most significantly, returning Indians routinely establish their own firms, rather than return to work for big multinational corporations or local firms.

The government could play a catalyzing role by strengthening the support infrastructure for diaspora knowledge initiatives. To help unleash the benefits of India's innovation potential, the government of India may wish to explore new initiatives that exploit the huge talent of the Indian diaspora. The public policy rationale of these initiatives is based on information asymmetries and uncaptured synergies from activities whose social benefits exceed their private ones. Activities could include joint research projects; spin-offs; short visits and seminars; assistance in formulating innovation strategies and methodologies; program design, implementation, and evaluation; institutional reviews; participation in teaching at management bodies of key institutions; mentoring; and liaisons with technology institutions and markets. To deliver on the promise of a diaspora-facilitated circle of economic growth and reform, a new generation of diaspora initiatives may be desirable. This could include establishing a more formal diaspora network (following the highly successful Global Scot, a network of 850 influential Scots abroad managed by the Scottish Enterprise), and building on existing groups that aggregate this population's talent and capital for use in India through a dedicated fund that could, among other activities, enrich innovation policy program and institutional design; enrich the management of scientific institutions and programs; provide teaching, consultancy, and mentoring resources for Indian innovators; and assist in the commercialization of Indian IP within India and abroad.

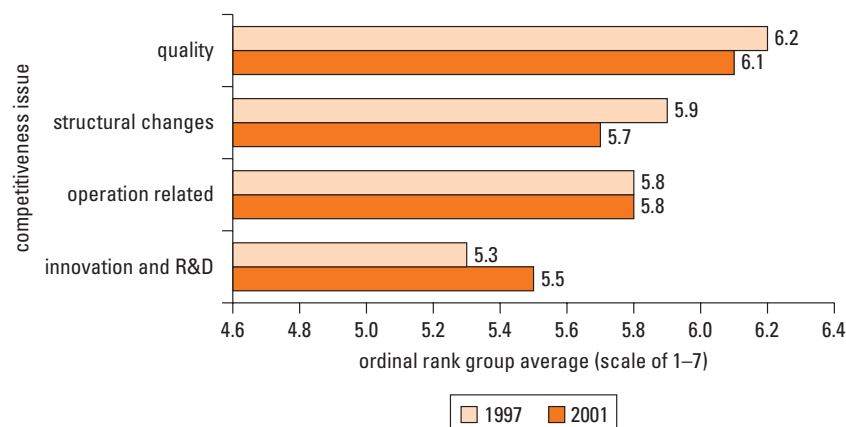
Improving the Diffusion and Absorption of Metrology, Standards, Testing, and Quality Services

Standards and quality are closely linked to innovation and productivity. Quality standards supported by a national metrology, standards, testing, and quality (MSTQ) system can contribute to enterprise competitiveness, innovation, and trade. They do so by improving information flows and allowing customer differentiation, thereby promoting quality and enhancing competition. Standards also embody technology, acting as a channel for technology diffusion and so enhancing productivity. The importance of metrology—especially with respect to trade—is fast increasing given increasing globalization and trade of subcomponents and services, making it more complex than traditional arm’s-length transactions.

As reported in chapter 1, the World Bank’s 2006 Enterprise Survey suggests a positive association between enterprises that have received an internationally recognized quality certification and available indicators of innovation outputs, such as developing new product lines and upgrading existing product lines. On the innovation input side, indicators of absorption—such as acquiring knowledge through the use of new machinery and equipment or seeking technology transfer through licenses—are also positively associated with having received quality certification. Innovation outputs in India, in turn, are positively associated with productivity. Beyond India, empirical studies based on international trade models find that harmonized or shared standards are trade promoting, while idiosyncratic national standards can create a competitive disadvantage for exporters. Evidence from other countries also suggests that standards can contribute to enterprise productivity.⁹

Quality is a key competitive priority for Indian enterprises. Surveys of Indian manufacturing enterprises highlight the strategies adopted to improve their competitiveness (Chandra and Sastry 2002). Figure 3.4 shows the relative importance given to four sets of issues by Indian firms over two surveys, conducted in 1997 and 2001.

Figure 3.4 Competitive Priorities of Manufacturing Enterprises, 1997 and 2001



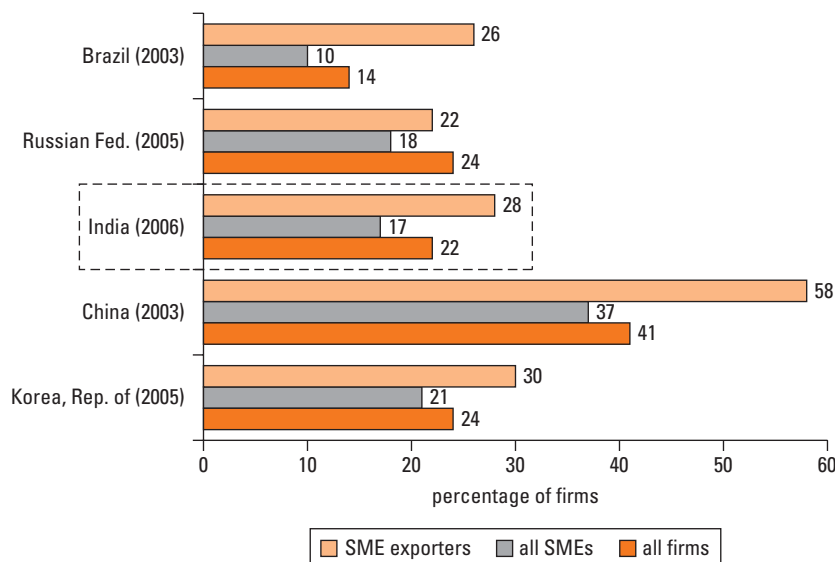
Source: Chandra and Sastry 2002.

Quality remains the top competitive priority of Indian firms. The priority assigned by firms to quality and structural changes (which include ability to change product mix, fast delivery capabilities, and low price capabilities) has increased since 1997—indicating that enterprises recognize the importance of making changes in manufacturing systems, processes, and practices to enhance competitiveness. But the priority that surveyed enterprises have assigned to invention and R&D has fallen since 1997. This has implications for long-term competitiveness because manufacturing needs to be backed by new product introductions and new processes, both domestically and in exports.

The absorption of quality in India and the use of its MSTQ system appear to be low relative to comparator countries. Figure 3.5 presents evidence from available comparator countries in response to World Bank Enterprise Survey questions about whether enterprises have received an internationally recognized quality certification (such as ISO 9000, 9002, or 14000, or sector-specific certifications such as those by the international food safety management entity Hazard Analysis and Critical Control Points). Results are reported controlling for differing percentages of small, medium, and large enterprises across surveys by weighting countries relative to India's size. For coverage of quality certification across all enterprises, India is in the middle of this group at 22 percent of enterprises, having adopted quality certification ahead of Brazil (14 percent), just behind Russia and Korea (both at 24 percent), but significantly below China (41 percent). Coverage of quality certification is lower across all countries by smaller enterprises.

Given the expected strong positive correlation between adopting internationally recognized quality certifications and exporting, and the stronger likelihood for larger

Figure 3.5 Enterprises with Internationally Recognized Quality Certification



Source: World Bank Enterprise Surveys.

Note: SME = small and medium enterprise.

firms to adopt such standards, results are also reported for small and medium exporters. Here, India's position at 28 percent of enterprises being certified is insignificantly different from those of Brazil (26 percent), Russia (22 percent), and Korea (30 percent)—but significantly below that of China (58 percent). Informal interviews conducted in preparing this volume support the implication of low absorption of quality in India—namely, that the use of MSTQ services, especially by smaller enterprises, is quite low. The reasons cited for low use include a lack of incentives in an insufficiently competitive environment in many sectors, low awareness about the benefits of MSTQ services, relative high costs and low availability of services economywide, outdated facilities, and a poor customer service orientation of main providers.

India's standards and quality system is serviceable but dominated by the public sector—and use by private enterprises is low. India has a fairly well-developed system of MSTQ institutions and regulations, meeting most international requirements. But some of its facilities are old (such as metrology and testing labs), and others lack adequate capacity (such as for accreditation and conformity assessments) to meet the needs of fast-growing, modernizing Indian enterprises:

- The National Physical Laboratory is the apex body in metrology and has good coverage in physical metrology. However, its labs are scattered in many old buildings, and in most cases have old equipment and lack adequate skilled staff.
- The Quality Council of India is an autonomous body responsible for establishing and operating the National Accreditation Structure for conformity assessment bodies. It also handles registration of quality management personnel and training organizations. But its coverage is not widespread: many testing and conformity bodies set up by various ministries are outside its mandate.
- The National Accreditation Board of Testing and Calibration Laboratories has more than 650 accredited calibration and testing laboratories in the public and private sectors.
- The Bureau of Indian Standards is engaged in the formulation of Indian standards, certification, and product testing. It is the inquiry point for the World Trade Organization (WTO) and training. Under the WTO, health, safety, and environmental regulations are the government's responsibility. However, several sectors are not under such regulation in India, such as telecommunications, toys, and fire safety equipment.

Taking into account the high potential for growth of smaller enterprises, as measured by productivity, output, employment, and exports, in 1999 the government created a special ministry that in 2001 was split into the Ministry of Small Scale Industries and the Ministry of Agro and Rural Industries. Box 3.2 presents some of the initiatives to promote quality supported by the Ministry of Small Scale Industries. However, as with government programs seeking to foster absorptive capacity, there is insufficient evidence on the reach, use, and effectiveness of these programs.

Box 3.2 Ministry of Small Scale Industries: Selected Metrology, Standards, Testing, and Quality Initiatives

Many countries have designated a nodal agency to coordinate government interventions to support small and medium enterprises (SMEs). In India, a separate “medium enterprises” sector is not defined. The Small Industries Development Organization, under the Ministry of Small Scale Industries, serves as India’s nodal development agency for small enterprises. It focuses on providing support in the following areas:

- Technology and promotion, including MSTQ support and technology upgrading (see box 3.3)
- Marketing, including subcontracting exchanges, vendor development, bar coding, and participation in international fairs
- Entrepreneurship development, including training at national institutes and entrepreneurship development courses
- Promotion of self-employment, including a program for unemployed youth sponsored by the Ministry of Agro and Rural Industries
- Infrastructure, including upgrading of industrial estates
- Facilitation, including product reservation, SENET (Small Enterprise Information and Resources Network for Electronic Information support), incentives for backward areas, and national awards for entrepreneurship and quality.

Quality-related support and promotion schemes by the Small Industries Development Organization include the following:

- *Testing centers.* Four regional testing centers (New Delhi, Mumbai, Kolkata, Chennai) and seven field testing stations (Jaipur, Hyderabad, Kolhapur, Pondicherry, Bhopal, Bangalore, Chengannacherry) provide enterprises with quality-related testing services, calibration services (including those covered under ISO 9000, to meet their mandatory requirements), and assistance in meeting export-related quality requirements. The centers and stations also provide training in testing and calibration to strengthen worker skills, and coordinate with the Bureau of Indian Standards and other technical testing and inspection organizations on matters related to standardization of products for small enterprises. The four regional testing centers have been accredited by the National Accreditation Board of Testing and Calibration Laboratories. Their performance over the past five years has been relatively stable, achieving 65–70 percent self-sufficiency each year. The performance of the field testing stations improved during this period, with the self-sufficiency ratio rising from 67 percent in 2001–02 to 88 percent in 2005–06 (and reaching 93 percent in 2004–05).
- *Testing laboratories run by associations of the Ministry of Small Scale Industries.* A scheme initiated in 2001 helps establish testing centers for industry associations and modernize and expand quality marking centers for state governments. The scheme provides matching grants of 50 percent (up to Rs 50 lakh, about \$120,000) to set up the centers.

(continued)

Box 3.2 continued

- *ISO 9000 awareness program.* This is a one-day program of awareness and five-day motivational and educational program on total quality management and the ISO 9000 total quality system, organized by Training Resource Centers and Small Industries Service Institutes (see box 3.3). As a result of the programs, the number of small enterprises availing themselves of the benefits of reimbursement increased from 122 through the end of Eighth Plan to 1,384 through March 2001.
- *Incentive scheme for ISO 9000 and ISO 14001 certifications.* This scheme reimburses charges for acquiring ISO quality management and environmental management certification, covering 75 percent of the costs (up to Rs 75,000, about \$1,800).
- *National awards for quality products.* Annual awards are given to encourage small-scale entrepreneurs to upgrade the quality of their products, develop new technologies and designs, and deliver technological improvements. The first, second, and third prizes carry (besides a trophy and certificate) cash awards of Rs 25,000, Rs 20,000, and Rs 15,000, respectively, or between \$350 and \$600. The awards are given to entrepreneurs in each applicant state or Union Territory.

Source: Authors, based on information at <http://ssi.nic.in/>.

India should modernize its MSTQ infrastructure to international standards to meet the needs of its growing economy. The government should undertake the following:

- Review the functioning of all MSTQ programs, including their governance and management structures and effectiveness—with a view to improving their operational effectiveness and maximizing synergies between initiatives sponsored by various line ministries, with a focus on the Ministry of Small Scale Industries.
- Increase industry awareness of MSTQ services and their importance, including through better interaction with industry organizations and incentives (such as matching grants) for SMEs to use MSTQ services and obtain national and ISO certifications.
- Create a world-class metrology infrastructure (separating it from the National Physical Laboratory) with state-of-the-art metrology laboratories, including modern buildings and equipment, and upgraded staff skills. This move should be accompanied by specialized metrology capabilities developed in existing national labs—such as food-related metrology at the Central Food Technological Research Institute and biology metrology at the Centre for Cellular and Molecular Biology.
- Strengthen other MSTQ institutions such as the Quality Council of India, accreditation boards, and other bodies.

- Increase private participation in testing and accreditation labs. Most government accreditation and testing labs should be considered for privatization or at least private management.
- Review areas under regulation to identify uncovered sectors—for example, toys and health services have almost no standards regulations, yet affect a huge part of the Indian population.
- Consider bringing under the purview of the Quality Council of India many accreditation programs set up and managed by various ministries, to foster national consistency and avoid conflicts of interest.
- Encourage and support participation by Indian scientists and MSTQ personnel (public and private) in international technical committees, working groups, workshops, and seminars.

Strengthening the Absorptive Capacity of Micro, Small, and Medium Enterprises

A useful way to help less-productive enterprises better absorb knowledge is to create an environment where they can learn from more productive firms. Larger firms tend to be better at absorbing knowledge and are more likely to have innovative outputs (see chapter 1). Of course, it is not realistic to expect all Indian firms to operate at the level of more efficient, typically larger firms. Constraints include the skills and education of managers; skills of workers; age and technological vintage of firm equipment and processes; access to capital, information, and other inputs; and access to customers and marketing strategies. Enterprises need to have the capacity to search for appropriate knowledge, evaluate different technologies, modify off-the-shelf technologies for use, and integrate these new technologies into their production processes.

These are not easy tasks, especially for smaller enterprises lacking established buyer-seller networks. Among other factors, a dense network of links to larger (foreign or domestic) enterprises may be a critical prerequisite for the emergence of dynamic smaller enterprises. A business environment that facilitates commercial transactions for all firms—large and small—and helps build links with other smaller enterprises and with dynamic larger enterprises as qualified suppliers appears important for promoting better economywide knowledge absorption.

Although the government has introduced a range of programs to promote technology absorption by smaller enterprises, including support for cluster development, no quantitative analysis exists on their effectiveness. The policies, programs, and schemes administered by the Ministry of Small Scale Industries to help small enterprises link up with large ones—to increase productivity and competitiveness—include a number of technology initiatives to help them assess options and receive support for upgrading technology.¹⁰ As a key strategy for enhancing the productivity and competitiveness of small enterprises, the ministry is supporting cluster development as part of its new Small Industries Cluster Development Program. The

idea behind the cluster approach is not to pick winners but rather to support enterprises that show market potential. Thus, the selection of clusters requires evidence on the viability of the cluster and the vibrancy of local support institutions, together with the existence of gaps in technology, product quality, common facilities, skills upgrading, and marketing support. Although this program—and a range of others described in box 3.3—seem to be addressing relevant needs, spending by the Small Industries Development Organization on technology upgrading seems small relative to economywide needs. More important, systematic and independent assessments of each program should be undertaken to offer recommendations for scaling up or downsizing.

The absorptive capacity of smaller enterprises should be further strengthened, among other ways, by expanding support programs—but only after their effectiveness has been ascertained. TIFAC and the Ministry of Small Scale Industries recently initiated a joint, cross-ministerial program for upgrading selected SME clusters, with

Box 3.3 Ministry of Small Scale Industries: Selected Technology Upgrading Initiatives

The ministry's technology support includes a variety of mechanisms to provide enterprises with information and support about technology options:

- *Tool rooms and tool design institutes.* To help enterprises upgrade their technology, the Small Industries Development Organization has set up 10 facilities equipped with the latest imported equipment—such as for computer-aided design (CAD), computer-aided manufacturing (CAM), and computer numerically controlled (CNC)—as well as other tools meeting international standards.
- *Product and process development centers.* Six facilities for different industries (such as fragrance and flavor development, glass, electronics, and design of electrical measurement instruments) advise enterprises on how to improve quality and productivity through R&D, product design, product and process improvements, and common facilities.

Technology promotion schemes include the following:

- *Small Industries Cluster Development Program.* Launched in 2005, this program (formerly the Integrated Technology Upgrading and Management Program) addresses the productivity concerns of small enterprises, and applies to any cluster where there are common production methods among enterprises. The program includes a technology diagnostics and needs study, scouting for appropriate technologies, facilitation of research to adapt available technology, intervention at one enterprise so nearby enterprises can see and feel the impact of technology upgrading, training, and dissemination. The Ministry of Small Scale Industries does not contribute more than 80 percent of the total cost of any cluster project, up to a

(continued)

Box 3.3 continued

ceiling of Rs 10 crore (\$240,000) per project. The pioneering enterprise has to bear 50 percent of the costs of setting up the demonstration plant.

- *Technology Resource Centers.* In 2001, 21 Small Industries Service Institutes were converted into technology resource centers to help enterprises that want to upgrade their technology, by providing information about state-of-the-art technology, lists of machine suppliers, quality standards and consultants, and Internet access to electronic journals, catalog downloads, and advanced search facilities, as well as organizing technical training programs.
- *Mini tool rooms and training centers.* The central government assists state governments through 90 percent grants for machinery and equipment costs for new mini tool rooms and 75 percent grants for upgrading existing mini tool rooms. Mini tool rooms and training centers help enterprises gain access to required tools to absorb new technologies, provide training in tool design, provide consultancy and information to solve problems related to tooling, and act as common facilities to assist enterprises in product and prototype development.
- *Technology Bureau for Small Enterprises.* This bureau provides technology information (online databases on technology options), match-making (networking and assistance in drafting agreements and preparing business plans), finance syndication (loans, venture capital, and interest-free loans to meet initial expenditures in the pretechnology absorption stage), and business collaboration (support for exporting technologies), as well as support services (arranging consultancy services and visits of overseas experts, and coordinating buyer-seller meetings). The bureau is a joint initiative between the United Nations Asian and Pacific Center for Transfer of Technology, the Small Industries Development Bank of India, and the Small Industries Development Organization.
- *Credit-Linked Capital Subsidy Scheme for technology upgrading.* This scheme aims to facilitate technology upgrading by providing upfront capital subsidies to small enterprises for modernizing their production equipment and techniques. The ceiling on loans is Rs 1 crore (\$24,000), and the subsidy rate is 15 percent. The Small Industries Development Bank of India and the National Bank for Agriculture and Rural Development are the nodal agencies for the scheme's implementation.

Source: Authors, based on information at <http://ssi.nic.in/>.

the goal of making them globally competitive.¹¹ One direction for further programmatic reform is to explore collaboration through public-private partnerships with universities, labs, and private corporations, to help ensure that knowledge provided to local SME clusters is constantly refreshed, reflects international best practice, and is as market-driven as possible. Such programmatic support should also be linked with complementary initiatives to build appropriate skills and education, to ensure more effective absorption.¹² However, when deciding which programs to expand and which to downsize or close, quantitative assessments of their reach, use, and

effectiveness are essential. This should be a short-term priority. Based on such evaluations, programs that appear effective could be candidates for expansion, while ineffective programs should be discontinued, with funds reallocated flexibly across programs depending on periodic reassessments of their effectiveness.

Notes

For questions or further information, please contact Vinod K. Goel (vgoel@worldbank.org), Mark A. Dutz (mdutz@worldbank.org), or Carl Dahlman (carl.dahlman@gmail.com)

1. To be aligned as closely as possible with “small-scale industrial undertakings”; as defined by the Ministry of Small Scale Industries, small enterprises are defined here as those employing 15 or fewer workers. Although small-scale industries are defined according to assets (for example, where investment in fixed assets in plants and machinery does not exceed Rs 10 million), average employment per unit in urban areas is 10 staff, with urban beverage and tobacco producers leading with 31, followed by textile producers at 18, and basic metal industries at 13.
2. To reduce false readings from poor data, the top and the bottom 1 percent have been dropped from the sample. An “adjusted” maximum was then calculated for each sector, at the point where the distribution begins to look more like a normal distribution; these “adjusted” frontiers are roughly 60 percent of the actual maximums.
3. This point is just to illustrate the importance of using existing knowledge. It is unrealistic to expect that all firms could operate even at the level of the better domestic firms. Getting to those higher levels would require investments in physical, human, and management capital that are not costless. In addition, it cannot be assumed that output could be almost quintupled and that it could be sold, or that all workers would remain employed if there were such tremendous increases in productivity.
4. This section focuses on direct knowledge flows to enterprises engaged in international activities, not the subsequent spillovers to other local enterprises through demonstration effects, labor turnover, or copying and reverse engineering.
5. See Westphal, Rhee, and Purcell (1981) on how important this was for upgrading technology for firms in the Republic of Korea.
6. See Comin and Hobijn (2004) on the former, Lederman and Maloney (2003) on the latter.
7. Figure 10.1 in *Doing Business 2007* (World Bank 2006a) shows the negative correlation between FDI and time to enforce a contract. Qian and Strahan (2006) find that small businesses get better financial terms on loans when contracts can be enforced quickly and cheaply. Cooley, Marimon, and Quadrini (2004) find that new technologies are adopted faster when courts are efficient, because new businesses—as the predominant innovators—do not have the clout that larger firms do to resolve disputes outside the courts.
8. For instance, rather than structuring payments as burdensome upfront, prelaunch start-up costs, allow payments through equity or from future revenue streams from use of the technology.
9. Swann, Temple, and Shurmer (1996) find that standards have a positive effect on intra-industry trade exports and imports between Germany and the United Kingdom. Adopting 100 additional British standards raises the U.K. export/import trade ratio by roughly 14 percent. Blind and Jungmittag (2005) find that specifically harmonized standards enhance German trade. Regarding the productivity link, DTI (2005) reports that standards contributed to roughly 13 percent of the growth in labor productivity in the United Kingdom between 1948 and 2002.
10. See www.smallindustryindia.com/thrustareas/technology.htm.
11. Seven sectors have been identified for initial detailed assessments: casting, sporting goods (Jalandhar, Punjab), scientific instruments (Ambala, Haryana), rural pottery, low-end surgical instruments (Kolkata), diesel pumps and electrical motors (Rajkot, Gujarat), and agricultural tools (Karnal, Haryana). The studies will assess technology products and processes in each

sector relative to international best practice, identify gaps (use of new materials, skill deficiencies, market requirements and competition, and availability and use of existing programs and initiatives), and suggest possible interventions to bridge identified gaps, including involvement of academia or R&D institutions.

12. See complementary recommendations in chapter 5.

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Promoting Inclusive Innovation

Anuja Utz and Carl Dahlman

A cross-cutting, multipronged strategy is needed to make India's innovation system better meet the needs of the common people. Most discussion on India's innovation system focuses on formal research and development (R&D) efforts and the formal part of the economy. However, India is an extremely heterogeneous economy, and most of its population operates in the informal sector. Given the rising divergence between productivity in agriculture and in knowledge-intensive professional sectors such as information and communication technology (ICT) and finance, and the economy's inability to sufficiently absorb migrants from the agricultural sector and new entrants to the labor force, income inequality will likely increase. This has been the trend in most other economies—especially fast-growing ones. Inequality is also likely to worsen unless special efforts are made to address the needs of the poor.

This chapter outlines some mechanisms to support innovation efforts that can help improve the productivity and livelihoods of people in India's vast informal economy. Much of the knowledge and technology needed to achieve the Millennium Development Goals (MDGs) already exists. Much is known about basic nutrition, sanitation, preventive medicine, environmentally friendly technologies, cheap mobile phones, and the like. But poor people's needs are broader than the few listed and monitored as part of the MDGs, and further innovation is required to improve delivery of a wide range of public services. Far more needs to be done on preventive medicine, clean water, education, and other public services that can benefit from harnessing collaborative efforts of formal creation efforts for the poor. What is needed is not only to reduce the costs and increase the availability of goods and services needed by the poor, but more important, to open up sustainable livelihood and productive income-generating opportunities for the poor.

Poor people's innovative ability is constrained by, among other things, insufficiently developed skills, inadequate public services, and an inability to access markets and assets on fair terms and handle associated risks. Enhancing skills through better

delivery of basic training for the informal sector is discussed in chapter 5. How innovation through access to new and existing technology can help create more and better-paying jobs for enterprises that the poor work in or run has not received enough attention, and is a major focus of this chapter. In addition to strengthening poor people's capabilities, solutions will involve strengthening incentives, policies, and institutions. Part of the solution will be in stronger institutional infrastructure. In addition to closer collaboration between public R&D entities, industry, universities, nongovernmental organizations (NGOs), and global networks to better meet the needs of the poor, the poor could gain by organizing themselves in groups. In Andhra Pradesh, community-based development initiatives have led self-help groups to develop mutual insurance schemes, lending and savings operations, and marketing strategies for new agricultural products. Although this chapter illustrates the potential of new and existing technologies in opening up some of these opportunities, a lot more needs to be done.

Harnessing Formal Creation Efforts for the Poor

A first approach to promoting inclusive innovation is for India to harness, increase, and redirect formal creation efforts to better meet the needs of the economically weaker sections of Indian society. The main recommendation of this section is to create incentives for pro-poor early-stage technology development (ESTD) and commercialization by the formal sector, possibly by providing more preferential matching grants to collaborations among public R&D entities, industry, universities, NGOs, and global poverty alleviation networks.

Agricultural R&D as Inspiration

India's green revolution is the foremost example of harnessing formal creation efforts for achieving national self-sufficiency in food grains. Over the past four decades, the green revolution has significantly improved India's food security and reduced rural poverty. It has included investments in technology, largely comprising high-yielding seed varieties (initially of wheat and later rice), chemical fertilizers, and agricultural research and extension—aided by public investments in supporting infrastructure (irrigation, roads, market institutions) and price incentives that have encouraged wheat and rice production.

Although India's agriculture faces many challenges, it also has great technological opportunities. There is huge untapped potential for augmenting value chains in agriculture through crop diversification and forward and backward linkages, including post-harvest handling and processing. First, the rich diversity of agro-ecosystems is a source of sustainable growth for the sector. Second, joint ventures between public research institutes and the private sector are seen more favorably today. Such partnerships could considerably augment R&D efforts. Third, agriculture can develop value chain processing activities in rural areas to meet the changing pattern of food demand in the country and to tap international markets. Fourth, crop diversification

has become a potential source of agricultural growth, creating new export and employment opportunities. Fifth, livestock, fishery, and horticulture are emerging as important sunrise sectors. Because most livestock is owned by small and marginal farmers and landless households in rural areas, the rapid growth of these sectors benefits poor households.

Agricultural R&D is crucial to generating additional income and employment for the poor. Given the limited scope for expanding agricultural areas, increases in productivity, profitability, and competitiveness will be the main sources of agricultural growth—led or triggered by innovations and applications of science in agriculture. In other words, Indian agriculture will shift from resource- and input-based growth to knowledge- and science-based growth. Flows of knowledge and innovations play a critical role in this paradigm shift. R&D assumes more importance because it is a cost-effective way of promoting sustainability and increasing competitiveness. To attain global competitiveness, more attention should be given to harnessing advances in frontier sciences in priority areas. Thus, support for basic and strategic research is critical. The consortia emerging between research entities and the private sector being promoted by the National Agricultural Innovation Project are a direction worth pursuing.

Building on Public R&D and University-Enabled Initiatives

India's large, diverse public R&D infrastructure has the potential to address more of the problems of the poor. As noted in chapter 2, the bulk of India's public R&D infrastructure is mission oriented to defense, space, and energy, with much less applied to problems of agriculture, industry, and health. Much more can be done to orient the considerable capabilities of this large public research system to address the needs and problems of the poor. Some of this harnessing is occurring in mission-oriented programs such as space, and a number of initiatives are under way in biotechnology, medicine, and industrial R&D (box 4.1).

The Council of Scientific and Industrial Research's (CSIR's) development of technology applications for rural India is a candidate for expansion, with the need for greater emphasis on commercialization (CSIR 2004). CSIR has been increasingly concentrating on a people-oriented development and delivery approach. CSIR labs, for example, have been instrumental in reviving India's world-famous handmade blue pottery, with research leading to product and quality improvements and product diversification—enabling this ailing traditional industry to find new life and extended markets outside India. Another example is technology to desalinate water using reverse osmosis. CSIR labs have also been designing multichannel ceramic membrane with optimum channel configuration to upgrade technology for purifying arsenic contamination in groundwater. CSIR has also been working on herbal products, mint oil (from the Central Institute of Medicinal and Aromatic Plants, Lucknow), food processing technologies, leather processing technology, and more. Although it has developed many pro-poor products and technologies, its transfer and commercialization have been weak.

Box 4.1 Public Research for Development

Using space technology for development. Advances in space-based Earth observation technology and its applications have the potential to integrate diverse sciences to provide economic security and better living standards. For example, Sujala, a watershed development project in Karnataka, has created hope for 1,270 villages across five districts, relying on high levels of community participation and scientific planning tools like satellite remote sensing, geographic information systems, and information technology (Muniyappa, Ranganath, and Diwakar 2004). Similarly, under the Rajiv Gandhi National Drinking Water Mission, more than 2,000 ground-water maps covering about 45 percent of the country (mainly problem zones) have been prepared, and more than 24,000 wells drilled (Mohandas and Reddy 2004).

Preventive medicine. The new antituberculosis molecule (LL-4858 Subotern) by Lupin is an example of network innovation through a public-private partnership. The Council of Scientific and Industrial Research supported this project through the New Millennium Indian Technology Leadership Initiative (NMITLI). The molecule has the potential to not only treat tuberculosis but also significantly reduce treatment time, and is compatible with combination therapy. The molecule has been tested on mice and guinea pigs and has been proven very effective. An investigational new drug application has been made. Once cleared, the molecule will go through clinical trials (Bowonder and others 2006).

Source: Authors.

India's extensive university system can also do more. Except for the Indian Institute of Science and Indian Institutes of Technology (IITs), most Indian universities do little R&D. But they have the bulk of scientists and engineering PhDs, so have considerable intellectual capital that can be deployed to work on the technological problems of the poor. Some good initiatives in this area can be built on (box 4.2).

Stronger incentives and funding are needed to harness the potential of public R&D and university-enabled initiatives. Available mechanisms to increase the focus on inclusive innovation include institutional mandates, prizes and public awards, and targeted funding. As a policy thrust, the government should encourage research institutes, universities, and other publicly funded learning institutes to do more to address the needs of the poor—for example, through competitive research grants. Prizes and public awards could be given to research teams and institutes that produce relevant innovations. Mechanisms—including widespread dissemination and funding—should be offered to scale up, demonstrate, and disseminate these innovations to people in the informal sector. The precise nature of transfer and dissemination mechanisms will depend on the nature of the innovations and their potential applicability. Those with the nature of public goods should be widely demonstrated and disseminated among the target population. One possible mechanism would be to create a professional body entrusted with in-field trial and demonstration for diffusion, adaptation, and assimilation of formal sector technologies for the poor. Such

Box 4.2 University-Enabled Initiatives

n-Logue. Incubated at IIT Chennai, n-Logue (www.n-logue.com) can best be described as an Internet service provider for rural areas (Manzar 2005). It was launched to fill the need for Internet and voice services in underserved small towns and villages; the company does not operate in any of India's top 150 population centers. n-Logue has established 2,500 village information kiosks with dedicated broadband connectivity, offering agricultural, health consultation, education, and insurance services. The kiosks have been set up by village entrepreneurs, who take bank loans to finance the initial costs. The kiosks must generate revenues to repay the loans. The aim is to replicate the Public Call Office model throughout rural India so that it can help double rural per capita income (Das Gupta 2006). The International Finance Corporation's Grassroots Business Initiative is providing a grant to scale up n-Logue's telemedicine technology for districts in Tamil Nadu and Gujarat; it is also exploring e-pharmaceutical distribution. Jhunjhunwala, Ramachandran, and Ramachander (2006) find—in joint research conducted by n-Logue and Microsoft on 150 kiosks—that while only a few are profitable within 6 months, 60–70 percent report profitability within 6–24 months. Because most kiosks are reluctant to report their incomes and generally grossly underreport, having 60–70 percent report themselves profitable is significant.

Baluchari IIT Kharagpur computer-aided design (CAD) program. Baluchari is a sari design style from West Bengal. Previously only rich people could own such saris, because the handloom-based weaving took an average of six months of design. A new adaptation using CAD simplified the design by replacing the handloom with the Jacquard loom. The spread of the Jacquard loom was affected primarily through a cooperative, while the idea and initiation were those of the master weaver. A public research organization and IIT Kharagpur joined with the cooperative and secured ministry funding. The CAD program was user friendly, and the cooperative adopted and diffused the process very successfully within Bengal. The program has retained the original design style, and varieties are immense. CAD-designed Balucharis are in the market at low prices, and the size of the market and earnings of weavers have increased. More important, the production process remains household-based, and marketing—including sourcing of input materials and financing—remains based on master trader networks (Banerjee 2006).

Source: Authors.

an entity would hire professionals trained in market research and media planning, offering competitive compensation.¹ Innovations that can be commercialized should be licensed to qualified producers and organizations.

Encouraging Private Sector and Global Network Initiatives

There is even greater potential to harness the research capacity of the private sector to address the needs of the poor—as shown by the growing number of Fortune at the Bottom of the Pyramid initiatives. Efforts to develop products that meet the needs of

Box 4.3 Fortune at the Bottom of the Pyramid Initiatives

Solar energy for the poor. The Solar Home Systems program, launched as a three-year energy pilot in Karnataka by the United Nations Environment Programme and the Shell Foundation, works with two major Indian banks and nine agricultural subsidiaries to make loans to rural households seeking to buy solar lighting. By September 2005, the program had provided more than 100,000 people with reliable, affordable electricity for the first time.

Mobile telephones. Ultra low-cost handsets are being produced by Nokia and LG, reflecting the 5 million new mobile phone connections being added each month in India.

Simputer. Amida's Simputer is designed to enable word processing and e-mail, regardless of language. Prices for the computer range from \$240–480. It was developed for use in rural areas and for applications such as microfinance and e-governance.

Microlending. The SKS smart cards project is a microfinance project catering to marginal farmers and agricultural workers. SKS Microfinance is an innovative nonbanking financial company that has a variety of loan products, encourages membership of women, and provides loans of \$100 or less. So far it has loaned about \$57 million to more than 200,000 people. ICICI Bank has lent more than \$10 million to SKS and led multiple initiatives to provide affordable banking services to the poor. The bank has partnered with SKS, n-Logue (see box 4.2), and others to co-locate automated teller machines with rural Internet kiosks. It has also created a network of 8,000 self-help groups, each with 20 female members, to create microfinanced businesses.

Hypermarkets and access to cold storage supply chains for poor farmers. Over the 2007–10 period, Reliance Industries—India's largest private sector company, an oil, petrochemicals, and textile group—intends to build a nationwide retail network of 2,000 supermarkets and 1,000 larger hypermarkets based on a distribution supply system, an integrated “farm to fork” logistics supply chain. Reliance will not enter the farming business. Instead it will be the “off-taker of last resort,” relieving farmers of risk. It plans to revolutionize both farming and retail by investing \$5.7 billion by 2011 to modernize both farms and stores, connect them through a distribution system guided by the latest logistics technology, and create enough surplus to generate \$20 billion in annual agricultural exports.

Direct-to-home distribution network. Consumer goods firms such as Hindustan Lever are seeking new ways of doing business among the rural poor. Its Project Shakti recruits women to self-help groups that offer tiny loans—microcredit—to support a direct-to-home distribution network. The project already reaches 80,000 villages, and by 2010 expects to employ 100,000 “Shakti entrepreneurs,” covering 500,000 villages.

Low-cost Internet connectivity for poor villages. Indian Tobacco Company's e-Choupal initiative has equipped more than 6,000 villages with computers and satellite connections to the Internet—part of its agribusiness procurement network. Farmers can use the computers to check prices for their products and sell online, freeing them from middlemen who take a big cut of farm earnings. Once a commercially viable way has been found to provide a village with an Internet connection, it has many other potential uses, including for e-government, sales, education, and entertainment.

(continued)

Box 4.3 continued

Drishtee.com. This initiative delivers fee-based e-governance, education, commerce, and insurance services to rural populations in northern and northeastern India. These services are delivered through more than 700 kiosks owned and operated by local entrepreneurs. The International Finance Corporation's Grassroots Business Initiative is providing Drishtee with a grant to establish 50 new kiosks in Meerut, Uttar Pradesh.

Sources: Usher 2003; Shell Foundation 2003; Tata 2007; *Economist* 2005a, 2005b, 2005c, 2006; Sharma 2004; Bellman 2006; Prahalad 2004; Moreau and Mazumdar 2006.

the poor and underserved—while also creating viable business propositions—need to be pursued more systematically. As argued by Prahalad (2004), large companies can use their considerable technological, organizational, and marketing capabilities to create and deliver products and services for people at the bottom of the economic pyramid—those with incomes of less than \$2 a day—and make a profit doing so (box 4.3).²

Global networks provide another source of formal R&D to meet the needs of the poor. The best known of international public goods R&D efforts is the Consultative Group for International Agricultural Research (CGIAR), which was behind the green revolution. There are also major initiatives in medicine and pharmaceuticals, environment, and other areas in which India should continue to participate, such as in the Global Research Alliance (box 4.4).

The government should consider allocating more funds to encourage formal creation and commercialization efforts that focus on the challenges facing the poor. It could establish a pilot Inclusive Innovation Fund to support formal R&D by public R&D entities, the private sector, universities, and NGOs aimed at the needs of the informal sector, on a matching grant basis. These initiatives should be subject to continuous monitoring and evaluation. If successful, in the long term the government should earmark a small percentage of the federal public R&D budget to support an Inclusive Innovation Fund on a recurring basis—the funding should cover scaling up, piloting, testing, and taking to the market. Competition for scarce funds would be driven by transparent eligibility and evaluation criteria.

Initiatives should focus on the underserved community—the more than 800 million Indians living on less than \$2 a day. An additional incentive is that many solutions developed for poor Indians would also be applicable for the 4–5 billion poor people worldwide. Thus, firms can develop and pilot in India products and services that then may be marketed globally. In addition, the government could provide financial incentives and awards to research teams, institutes, and universities that produce relevant innovations, as well as dissemination and funding mechanisms to scale up, demonstrate, and disseminate innovations to people in the informal sector.

Box 4.4 International Public Good–Type Innovation Efforts

Agriculture. The Consultative Group for International Agricultural Research (CGIAR) is a strategic alliance of members, partners, and international agricultural centers that mobilizes science to benefit the poor. The hope of extending the productivity gains of the green revolution in India to other parts of the developing world was in large measure the impetus for the CGIAR. Recent achievements include releasing quality protein maize varieties in 25 countries on more than 600,000 hectares, breeding a selective strain of tilapia, adopting low-till farming practices on 1.2 million hectares across the Indo-Gangetic plains, and training more than 75,000 developing country scientists and researchers.

Medicine and pharmaceuticals. According to Grace (2005), at \$10 billion, India's pharmaceutical industry ranks 4th in the world in volume of production and 13th in value. India supplies 22 percent of the world's generic drugs and a significant proportion of the vaccines made for the developing world. India can take advantage of recent commercial opportunities, such as the U.S. President's Emergency Plan for HIV/AIDS Relief (PEPFAR). Now that the risk to generic companies of being sued by originators is gone, companies such as Ranbaxy, Matrix, and Aurobindo have taken up the offer to get generic antiretrovirals approved by the U.S. Food and Drug Administration under the expedited review process set up to support PEPFAR. India is also participating in global initiatives such as the International AIDS Vaccine Initiative (IAVI) and the Global Fund to Fight AIDS, Tuberculosis, and Malaria (GFATM). More funding will enable it to work on solutions that would benefit not only itself but also the world.

Global networks. India, through CSIR, is a member of the Global Research Alliance (GRA)—a global knowledge pool for global good committed to undertaking large-impact projects for the benefit of society.

Sources: CGIAR (www.cgiar.org), IAVI (www.iavi.org.in/overview.html); GFATM (www.theglobalfund.org/Programs/Portfolio.aspx?countryID=IDA&lang=en and www.usaid.gov/our_work/global_health/aids/Countries/ane/india_05.pdf); GRA (www.research-alliance.net/index.html).

Promoting and Diffusing Grassroots Innovations

A second approach to promoting inclusive innovation is for India to better promote and diffuse innovations by grassroots entrepreneurs. A main recommendation of this section is for grassroots innovation networks to be formally evaluated and supported.

Grassroots Innovation Networks

Grassroots innovation networks support efforts where traditional knowledge and innovative products emerge at the individual or collective level.³ Grassroots innovation programs focus on poverty alleviation programs based on local people's knowledge, innovations, and practices, largely produced and maintained at the grassroots level. In some cases value may be added by the formal science and technology sector, but the lead ideas or traditional knowledge emerge at the local level. The programs

Table 4.1 Grassroots Innovations: Activities and Actors

Activities	Government	Nongovernment	Private
Documenting and disseminating information	• National Innovation Foundation (NIF) • Department of Science and Technology (DST) • CSIR's Traditional Knowledge Digital Library (TKDL) • Ayurveda Yoga Naturopathy Unani Siddha and Homeopathy (AYUSH) • Grassroots Innovation Augmentation Network (GIAN)	• Honey Bee Network (HBN) • Society for Research and Initiatives for Sustainable Technologies and Institutions (SRISTI) • Foundation for Revitalization of Local Health Traditions (FRLHT) Community Biodiversity Registers (CBRs) • Kalpavriksh • Gene Campaign • Beej Bachao Andolan • Anthra	• Publications ◦ Eenadu's Annadata ◦ Adike Patrike; Malayalam Panorama ◦ Baliraja ◦ Prakurthi
Resource conservation		• FRLHT CBRs • Beej Bachao Andolan	
Value addition and experimentation	• DST's Technology Information, Forecasting, and Assessment Council (TIFAC) • CSIR • NIF • GIAN	• SRISTI • Rural Innovation Network (RIN) • Magan Sangrahalaya • Centre for Innovation, Incubation and Entrepreneurship (CIIE) at IIM-Ahmadabad	
Commercialization	• CSIR • NIF • GIAN	• SRISTI • GIAN	• Aavishkaar
Dissemination	• NIF	• HBN and network collaborators • SRISTI • Centre of Science for Villages (CSV)	
Finance	• DSIR Techno-entrepreneurs Promotion Program (TePP) • DST Science and Society Program	• SRISTI • RIN • NIF • GIAN	• Aavishkaar
Intellectual property rights protection programs and services	• NIF	• SRISTI	

Source: Mathur and Sinha 2006.

include a broad range of actors—government, NGOs, and the private sector—involved in a host of activities (table 4.1). The largest, best-known nongovernment programs are the Honey Bee Network (HBN) and the Society for Research and Initiatives for Sustainable Technologies and Institutions (SRISTI). The two largest government programs are the Grassroots Innovation Augmentation Network (GIAN) and the National Innovation Foundation (box 4.5). The government has also set up the Traditional Knowledge Digital Library (TKDL) to prepare a computerized database of indigenous knowledge on medicinal plants.

Box 4.5 Grassroots Innovation Networks: HBN, SRISTI, GIAN, and NIF

Honey Bee Network (HBN) and Society for Research and Initiatives for Sustainable Technologies and Institutions (SRISTI). The HBN consists of innovators (individuals, farmers, and entrepreneurs), policy makers, academics, and NGOs committed to recognizing and rewarding innovative ideas and traditional knowledge produced at the grassroots level (by individuals and communities) through local language interfaces. It seeks to protect the intellectual property rights of knowledge holders and follow the conditions they may advise under the concept of prior informed consent (PIC). SRISTI (www.sristi.org) was created in 1993 as a voluntary organization to provide financial and institutional backing to the HBN. SRISTI has organized 17 Shodh Yatras (journeys of exploration) and developed a multimedia, multilanguage database using graphics, photographs, and other audiovisuals. It manages KnowNet Grin—an electronic knowledge network of grassroots innovators, and GILD (Grassroots Green Innovations local language database). It has developed a multimedia kiosk node at the IIM-Ahmadabad: Gyan Manthan Kendra (GMK), village knowledge churning center to connect innovators across language and cultural barriers. At the international level, SRISTI has organized scouting contests, with awards given to grassroots innovators from China, India, and Vietnam. SRISTI has also focused on women's knowledge systems through the Sadbhav-SRISTI Sansodhan Lab—the Natural Product Lab. The major products that have been successful in the scheme of value addition include development of botanical pesticides and growth promoters and health healing formulations.

Grassroots Innovation Augmentation Network (GIAN). GIAN (www.gian.org) was developed in 1997 with seed money from the Gujarat government to link innovations, investment, and enterprises so that benefits could be shared widely among the community. GIAN provides small amounts of funding for prototype development, facilitates links between innovators and scientific and technological institutions, and identifies commercial enterprises interested in licensing product technologies from grassroots innovators. GIAN has established the Grassroots Innovations Design Studio (GRIDS) at the National Institute of Design, Ahmadabad, and has been recognized as a Scientific and Industrial Research Organization (SIRO) R&D institution by the DSIR. About 18 technologies have been licensed and benefits shared with innovators under the PIC framework. GIAN has facilitated the development of more than 61 enterprise efforts to manufacture and market innovations, and has filed 67 patents and 3 design registrations; 2 patents and 1 design registration have been granted. It has filed seven patents in the United States—three have been granted. A Patent Assistance Cell at GIAN West has been established to assist small and medium innovators. GIAN has arranged for micro venture finance and incubation support for more than 60 innovations. GIAN West was the joint winner of the National Award for Technology Business Incubator in 2003, and one of the technologies it incubated—the cotton stripper machine—received an award.

National Innovation Foundation (NIF). The work of the HBN and SRISTI has been the model for the NIF (www.nifindia.org), set up by DST with an initial grant of about \$5 million. It is a formal effort to document grassroots innovations and traditional knowledge, and has a repository

(continued)

Box 4.5 continued

of more than 50,000 practices. It received a Micro Venture Innovation Fund (MVIF) of about \$1 million with the help of SIDBI (Small Industries Development Bank of India), but so far it has disbursed only about \$54,000. The MVIF has made availability of risk capital a bit easier, but there remains a gap with the lack of the establishment of a dedicated fund for product development. Of the tens of thousands of grassroots innovations and traditional knowledge products scouted by NIF, few have been incubated. Ideally, NIF should plan to incubate at least 2,000 projects to obtain 20–30 major products—of which 2 or 3 may achieve major success.

Source: Mathur and Sinha 2006.

Although there has been a lot of activity on grassroots innovations, there has not been much assessment or quantification of how they have contributed to improving the livelihoods of people in the informal sector. What little evaluation has been done mostly lists activities and number of innovations. There is virtually no information on costs or impacts of the innovations, though there have been many and some have even been licensed in India and abroad. Conceptually there are some models for promoting inclusive innovations (box 4.6).

Grassroots innovations face five main challenges: high transaction costs of scouting and documentation, need for value addition, need for commercialization, need for finance, and unclear intellectual property rights (IPR). High transaction costs

Box 4.6 Models for Promoting Inclusive Innovations

- Grants can be provided for technical assistance to support scouting and documentation, value addition, prototype development, and diffusion.
- For commercialization, government could provide matching grants. This could be part of the window of the fund of funds (see chapter 7), where the government can require certain activities (such as investing in pro-poor innovations, spin-offs from R&D labs, and so on) in exchange for the funding.
- The government could also use procurement to promote inclusive innovations—for example, by specifying goods and services for the poor and encouraging competitive bidding to produce them, thereby generating a market.
- Finally, Bottom of the Pyramid initiatives already under way should be encouraged to achieve the right scale.

Source: Authors.

are inevitable in programs that support a large number of widely scattered informal innovators who have accumulated knowledge from years of trial and error, or incremental innovations in existing tools or agricultural practices. What is needed is good monitoring and evaluation to support grassroots innovations considered to be making positive contributions by a new pilot-inclusive innovation fund.

High Transaction Costs of Scouting and Documentation

Possible remedies, relying mainly on existing networks, include the following:

- Developing special campaigns through microcredit associations, innovator associations, and GIAN to scout traditional knowledge, pool best practices, and take products to the market
- Using radio and other media to expand the reach of the HBN and institutionalizing Village Knowledge Registers (such as plant breeders' rights) that would not be restricted to biodiversity knowledge
- Replicating the Shodh Yatras, Shodh Sankals, and Prayog Pariwar networks throughout the country
- Building more multimedia, multilanguage databases (like that developed by SRISTI; see box 4.5) on innovations and traditional knowledge in local languages.

Need for Value Addition

Most grassroots innovations are still at an early stage of indicating that something might work (such as in herbal medicine) or a minor improvement might emerge—both of which require much more analysis and testing to improve the value of the innovations. However, there are few facilities or labs to do such analysis, validation, and testing.⁴ Even where available, they are most likely beyond the financial means of grassroots innovators. Furthermore, as with most innovations, there is a need not only to make technical improvements, but also to do demonstrations and test marketing to evaluate the market potential of the innovations, which requires additional steps and resources and can be expensive. What is needed is the following:

- Develop a nationwide strategic plan to add value in local knowledge, innovations, and practices through contractual arrangements with public and private R&D institutions. This includes support for SRISTI's think tank—the Academy for Augmenting Sustainable Technological Inventions, Innovations, and Traditional Knowledge.
- Establish community farms where traditional knowledge holders can do experiments and demonstrate their technologies.
- Build national and regional technology networks for specific problems. Investments are needed to identify experts willing to offer their services at different terms (ranging from voluntary to deferred or upfront payments). Incentives must be created for their time-bound availability at the sites of innovators.

- Use ICT to facilitate communication among network members. A revamped portal like www.Indiainnovates.com can provide an online value addition and incubation platform.
- Develop common fabrication laboratories and testing centers for faster validation.
- Link up with the 100,000 Internet-enabled Common Services Centers being set up by the Department of Information Technology to extend the reach of grass-roots innovations.

Need for More Effective Commercialization

Two types of diffusion and dissemination efforts are required for commercialization. Most innovations are simple and low cost (such as a pulley that locks a rope in place so that the object does not slide back, or a simple agricultural tool), and take the drudgery out of some work. The cost of diffusing such products is often higher than the cost of the product itself. But because they are simple, low cost, and easy to replicate, such products can have large social impacts on the livelihoods and quality of life of marginalized sections of society. Diffusion of these types of innovations requires the following:

- Creating awareness of them through the media, and publicizing results of trials and demonstrations
- Networking with NGOs and other actors with outreach to communities, building feedback loops for adoption
- Creating a national fund to acquire rights to such technologies
- Contributing resources to support diffusion of open source public domain technologies (social technologies), governed by the prior informed consent (PIC) of the knowledge holders, communities, and individuals.

Other types of innovations are more complex and expensive, but they can raise productivity and increase competitiveness (such as a cotton-stripping motorcycle, cycle-based plow, or bamboo-splitting machine). Diffusing these will require explicit efforts to scale up for industrial production and significant marketing and commercialization efforts. Such efforts will require developing technology clearing-houses and exchanges to link grassroots innovators, investors, and entrepreneurs, as well as incubators such as GIAN to do market research, develop business plans, and source micro venture capital or risk capital to support innovators in becoming entrepreneurs. This could lead to a global GIAN that provides incubation support to people across the world.

Need for Financing Commercialization

Finally, even for innovations sufficiently developed to be commercialized, their industrial production and distribution need financing. This can be more expensive than the earlier stages, and it is difficult for grassroots innovators to get financing for this step (see chapter 7). Recommendations include establishing a fund for new

grassroots products and processes ready for commercialization, the terms of which could be softer than regular commercial financing. It is important that grassroots innovators learn about commercial principles. It is also important to learn from e-Choupal, Drishtee.com, and other initiatives on sharing information among potential private investors to set up venture funds or extend credit facilities for such commercialization (see box 4.3).

Pro-Poor Intellectual Property Rights

How can India deliver the benefits of IPR to poor citizens living traditional lifestyles? Any attempt to craft a traditional knowledge IPR framework that rewards functional knowledge from traditional communities will require revolutionary thinking and bold experimentation in both legislation and administration. Advocates of traditional knowledge are often split between their desire to protect secret knowledge in ways that preserve traditional communities and their desire to leverage that knowledge in ways that increase the resources and opportunities available to those communities. These goals, while both arguably worthy, are mutually exclusive. A pragmatic consideration suggests that preservation is unlikely to succeed. Commercially valuable secrets are notoriously difficult to preserve. Corporations that have done so successfully have developed complex, often expensive, procedures. Nothing comparable is possible at the level of traditional knowledge. If India wants to lead the world in addressing the intellectual property inherent in traditional knowledge, it must begin by explicitly adopting the goal of compensation.

IPR for traditional knowledge could offer solutions—and challenges. Professor Anil Gupta, the Executive Vice Chairperson of India's National Innovation Foundation (NIF), has clearly articulated the challenge of protecting functional IPR for traditional knowledge (Gupta 2002). Introducing new IPR for traditional knowledge will both impose immediate administrative costs and increase restrictions on the use of such knowledge. Thus, a proper analysis of such IPR must justify the system as generating internal benefits that exceed its costs. Neither India nor the world should reward possessors of functional traditional knowledge merely for possessing it—but they should reward those possessors for sharing their knowledge. The basis for the proposed IPR system for traditional knowledge must thus parallel the basis of the patent system: possessors of traditional knowledge must put their knowledge into full public view in exchange for temporary rights, revenues, or both. When that temporary period ends, the traditional knowledge will become part of the global knowledge base, freely appropriable by anyone who grasps it—and no longer subject to anyone's IPR. Box 4.7 examines possible system structures for traditional knowledge IPR.

Consideration should be given to creating an IPR policy think tank. The government of India should charge the proposed policy-oriented think tank with assessing the costs and benefits associated with individual IPR for traditional knowledge, a blanket TKDL license, and a voluntary fund. Adoption of any of these approaches, concurrent with or shortly after the launch of the TKDL, will establish India's leadership on this issue, and reinforce its image as a country taking bold, novel approaches to developing its innovation system, and its burgeoning role as a leading

Box 4.7 Approaches to Designing Intellectual Property Rights for Traditional Knowledge

Possibility 1. Develop a direct national traditional knowledge analog to the patent system. This “equitable” proposal places possessors of traditional and nontraditional knowledge on footings as equal as possible. This proposal raises many challenges, including establishing rules for publishing traditional knowledge to share knowledge with the world, circumscribing classes of ideas that qualify as traditional knowledge, defining “items” of traditional knowledge, determining an appropriate length for IPR for traditional knowledge (beyond which the published knowledge enters the public domain), identifying “owners” for each item of traditional knowledge, setting and publishing “reasonable and nondiscriminatory” licensing terms (including both prices and rights), designating conservators, specifying appropriate outlays for moneys collected, designating enforcers, and defining penalties for noncompliance or infringement, and drafting international cooperation treaties in the likely event of noncompliant multinational corporations (MNCs). A variant is an international direct traditional knowledge analog to the patent system. This proposal eases many coordination problems, but risks holding the entire venture hostage to international intransigence.

Possibility 2. Institute a blanket license for traditional knowledge IPR. This reduces the complexity of systemic administration and eliminates many direct incentives for innovation, but it may leave enough to spur volunteer or NGO efforts on collection and cataloging. However, it does not really address challenges in international coordination, enforcement, and distribution.

Possibility 3. Establish a voluntary fund and encourage MNCs to contribute funds related to the value that they extract from the TKDL. This raises standard problems of free-ridership and the general limitations of applying moral suasion to business decisions. It is easier to establish and begin quickly, and could lead to larger short-term pools of disbursable money than the other alternatives. It is likely to present the fewest problems of international coordination and participation.

Source: Abramson 2007.

player in the global knowledge economy. Recommendations here include completing work on the library to prevent international patenting of traditional knowledge, and soliciting further analyses of various approaches toward leveraging traditional knowledge into revenue streams.

Helping the Informal Sector Better Absorb Knowledge

A third approach to promoting inclusive innovation is for India to help informal enterprises better absorb existing knowledge. A main recommendation of this section is for government programs to more effectively promote knowledge absorption in the productive sector and extend the reach of markets to the common man.

Agricultural and Rural Extension Reforms Offer Examples

Traditional, supply-driven public extension systems in agriculture have been replaced by more flexible, market-sensitive support mechanisms. The green revolution in India was successful in increasing agricultural output, but by the 1990s the increased supply of wheat and rice had reduced commodity prices and farm incomes, and India's supply-driven extension system could no longer respond effectively to new challenges in agriculture. India's traditional training and visitation extension system stopped being effective at roughly the time the country achieved food security. The system worked well when relatively uniform technological packages had to be diffused rapidly to large numbers of producers in a short time, as with improved rice production technologies for irrigation farming. But the approach was abandoned with changing needs, given its inadequate interaction with the agricultural research system, inability to attribute benefits, weak accountability, and lack of fiscal sustainability (see Anderson, Feder, and Ganguly 2005). There is a growing realization that a rural development strategy is needed to focus on increasing farm incomes and rural nonfarm employment. China's successful program for developing rural nonfarm opportunities is premised on providing a flexible, demand-driven package of services—not just technology, but also information, technical assistance, marketing, and developing supply networks and supply chains (box 4.8).

The recent National Agricultural Technology Project has piloted a more market-oriented extension approach built around demand-driven market assessments, farmer organizations, and bottom-up governance. In particular, the extension component has successfully piloted farmer-centered, market-driven extension services with close links to researchers and farmers known as Agriculture Technology Management Agencies (ATMAs). ATMAs improve coordination among line departments, encourage public-private partnerships for technology testing and extension, and strengthen institutions for monitoring and evaluation at the state and national levels (box 4.9).

Extending Support to Markets and Networks at the Cluster Level

Support networks can help low-income workers raise productivity and incomes by teaching more efficient production methods. Informal enterprise, formal micro enterprise, and SME production chains of goods and services suffer from low-quality inputs, stock seasonality and accumulation, weak capital machinery, unavailability of prototyping and facilities for experimentation, lack of information on and exchange with markets—including for exports—and poor knowledge of how to manufacture goods. An illustration is provided by the plethora of roadside motor mechanic shops all over India. Millions of mechanics do all kinds of repairing, and their problem-solving abilities and novel solutions show that their talents can be harnessed to increase productivity and achieve business ends. However, most mechanics lack basic education and have no access to formal engineering or science training.

Box 4.8 China's Spark Program

With the emergence of rapidly growing, dynamic rural nonstate enterprises in the early 1980s, and with the Chinese government's determination to be more active in using science and technology developed in China in the real sector, in 1986 the Ministry of Science and Technology initiated the nationwide Spark Program. (Its name came from the Chinese proverb "A single spark can start a prairie fire," meaning that the spark of science and technology will extend over the vast rural areas of China.) Its overall objective was to help transfer technological and managerial knowledge from more advanced sectors to rural enterprises to support continued growth and development in nonstate rural enterprises—mostly town and village enterprises (TVEs)—and to help increase output and employment.

The program has spread to virtually every province in the country and has helped develop 66,700 projects and many more individual enterprises within them. As a result, some 20 million people have found employment in rural areas. Due to a TVE in Jingyang County in Shaanxi, per capita income in the county has almost tripled in five years. The Spark Program has achieved one of the primary objectives of China's agricultural policy: to stimulate and modernize the rural economy and improve the living standards of farmers and their families. Many factors have contributed to the program's success, such as the following:

- *Flexibility.* Farmers can select from a wide range of well-developed technologies (projects) to suit their districts.
- *Demand driven.* Participants choose from the projects within the program.
- *Income driven.* Joining the program provides the prospect of higher income.
- *Diffusion of known knowledge.* Technologies used in the program are generally already proven.
- *Local accountability.* Selection of the leader of a Spark Program project is in the hands of participants (subject to approval).
- *Support from local institutes.* The state provides financial support for training participants and for technical advice.
- *Sustainability.* Enterprises are funded almost entirely from bank loans and from capital raised by participants, not from government grants.
- *Market responsiveness.* Considerable effort is made to ensure that market outlets are available for the products of participating enterprises, with the program linked to local agricultural and industrial market systems.

One of Spark's main lessons is that successful execution of technical assistance requires full commitment and participation by all stakeholders. National ownership is important, and sound organizational setup and dynamic leadership for implementation are essential to project success.

Sources: World Bank 1998; Huang and others 2004; IDRC (www.idrc.ca/en/ev-55213-201-1-DO_TOPIC.html).

Box 4.9 The Experiences of Agriculture Technology Management Agencies

India's ATMA provide for decentralized, participatory, farmer-driven extension services and have institutionalized bottom-up planning processes through the preparation of Strategic Research and Extension Plans—based on participatory rural appraisals and Block Action Plans. The program relies on a group approach based on village groups, as well as training of volunteer farmers. ATMA support private extension initiatives by contracting NGOs to conduct extension responsibilities in selected areas, using farmer-to-farmer extension services provided by individuals or through farmer organizations, and forming partnerships with input providers (of seeds, fertilizers, crop protection chemicals) for demonstrations and farmer training. In most districts, farmers and other stakeholders have a sense of program ownership.

ATMA successes include diversification of production systems for higher income (for example, cultivation of high-value crops including flowers, fruits, vegetables, and medicinal plants), better natural resource management, integrated pest management, organic farming, well recharging, integrated plant nutrient management, resource conservation technologies, and development of new enterprises such as cashew processing, beekeeping, dairying, value addition through processing, and group marketing. Farmer interest groups have mobilized men, women, and young people to join common interest groups, such as producer groups for flowers, fruit, milk, and other products, as well as marketing groups for seed.

Training farm leaders in technology and leadership skills is important. Strong farmer organizations can be a positive link in the cost-effective provision of extension support to small and marginal farming communities, as well as an alternative to privatization of extension service. Farmer Advisory Committees are operational in most project blocks and are recognized by government line departments. However, internal conflicts between ATMA priorities and departmental responsibilities persist, and extension staff require considerable motivation to work in a farm advisory role with multiple funding sources.

Source: Janssen 2006.

Creating a network of such entrepreneurs and giving them better access to modern training, knowledge, quality assurance, and quality control training and finance could lead to them providing high value to customers—increasing productivity as well as incomes (Banerjee 2006).

A broad range of support networks have unrealized synergies, including research firms, enterprises, trade-entrepreneur networks, and NGOs. Formal researcher-academic networks typically do not have enough incentives to provide knowledge inputs to this bottom layer of producers. However, CSIR is building new innovation models by forging local partnerships, reaching out to the remote corners of India. A village called Athaoni, on the border of Maharashtra and Karnataka, is where Kolhapuri chappals (sandals) were until recently made using traditional techniques. Scientists from the Central Leather Research Institute helped reduce the processing time of producing the sandals—the stamping process was standardized and certain innovative changes were made in the design, based on

computer-aided techniques. But this was not a top-down process. The oldest man in the village was consulted, and today the institute has trained several hundred artisans—not only enhancing family incomes but also changing their perceptions of science and development.

Large enterprises may be encouraged to act as mentors for SMEs. The Tata Group may be interested in leveraging value addition through maintenance clinics. Upgrading roadside mechanic shops through access to more modern knowledge and practices could help them become part of this chain. Trader-entrepreneur networks are also important, including traders and wholesalers up to exporters, master-craftsperson traders, and guild masters. Recognition is needed for their roles in minimizing transaction costs, channeling market information, enabling informal contracting and close monitoring of least costs, providing finance, and providing designs and inputs, and sometimes even skilled staff. Among the clear advantages of producer cooperatives, professional organizations, and other NGOs is that they have lower direct personnel and infrastructure costs than do formal organizations carrying out similar functions. More important, they often have or can create or access informal networks that can facilitate their work—and their impact can be significant (box 4.10). The government as well as the private sector would do well to learn from their experience.

Box 4.10 NGO Initiatives and Rural Networks

Self-Employed Women's Association (SEWA). The association is engaged in manufacturing, crafts, and services, and has more than 420,000 members at the grassroots level. Export markets explored include Australia, Belgium, France, Germany, Italy, Japan, Spain, the United Kingdom, and the United States. SEWA's Trade Facilitation Center researches markets, improves communications between micro enterprises and their federations, carries out capacity-building and product development, and develops information and training software in local languages. It has commercialized the rural handicrafts industry, which sells women's goods through shops, trade fairs, and exports—in some cases adding \$175 to an embroiderer's annual income. Key results for the Trade Facilitation Center include \$307,000 in sales in 2006, a reduction in rejection rates from 30 percent to less than 9 percent, a state-of-the-art mainline production facility, and income generation for over 1,100 craftswomen in 2005 and 2006.

Krishi Gram Vikas Kendra (KGVK). The organization has pioneered the concept of "total village management" by providing sustainable income-generating opportunities and access to health care for the rural poor of Jharkhand, where 60 percent of the population lives below the poverty line. One example is its AGIVIKA (livelihood) research and training center, which builds skills and production capacity among the rural poor by training them to deliver services in primary health care, education, and water management for a small fee. In the past 33 years, KGVK has helped increase incomes of more than 10,000 people, and created over 3,000 self-help

(continued)

Box 4.10 continued

groups in 352 villages of rural Jharkhand. Key results include the formation of 78 farmer clubs that provide training and extension services to over 600 farmers, and two retail shops that have had over \$12,000 in sales.

Magan Sanghralaya and Centre of Science for Villages (CSV), Wardha, Maharashtra.

Magan Sanghralaya is the apex body of the CSV. CSV's objective is to identify technological problems in rural areas, find suitable interventions to mitigate them, and develop the mitigations in ways that can be adapted locally. It trains rural women in simple scientific skills and techniques, teaching marketing skills on how to sell, display, and store finished products. The center has helped develop 300 technologies for women, benefiting some 2 million women.

Prayog Pariwar. The essence of the Prayog Pariwar movement is regular meetings of farmers' groups to discuss practical problems and provide them with information on scientific practices. A key accomplishment is its efforts in carrying out the Scientific Grape Revolution in Maharashtra, involving thousands of farmers. Within 20 years, farmers with little experience in scientific farming are now believed to be India's leading grape cultivators, with annual turnover of nearly Rs 500 crore (about \$122 million).

Sources: SEWA: www.sewa.org, Treacy 2003, and www.ifc.org/gbi; KGVK: www.ifc.org/gbi; Magan Sanghralaya and CSV, Wardha, Maharashtra: Dabholkar at www.prayogpariwar.net.

The government should consider providing additional programmatic support to markets and networks at the cluster level—with a focus on helping informal enterprises better absorb knowledge. The development of linkages calls for the emergence of new partnerships among traditional knowledge systems, NGOs, user ministries, associations of village industries, panchayat raj institutions, and rural Indians. A number of initiatives have elements of such partnerships. For example, it would be important to monitor ATMs in agriculture and, if effective, expand them by providing increased funding. There is also a need to enhance absorptive capacity and extend the reach of markets to the poor through enhanced information, education, training, skills development, and finance. It is also important to strengthen indigenous clusters supported by trader-entrepreneurs, corporate parenting, and NGO networks. In the long run, developing a more formal programmatic approach would be helpful to serve as a focal point, provide funding as a stimulus, and ensure rigorous monitoring and evaluation of results.

Socially driven pro-poor innovations should also be encouraged. This is where companies go beyond the pure profit motive to develop goods or services to help deal with the needs of the poor, such as basic literacy, preventive medicine, and health-related issues, in the spirit of corporate social responsibility (box 4.11).

Box 4.11 Indian Initiatives for Corporate Social Responsibility

Education. The Computer-Based Functional Literacy (CBFL) Program (www.tataliteracy.com) tries to overcome illiteracy through the innovative use of information technology. It uses a mix of teaching software, multimedia presentations, and printed materials to teach uneducated people to read in a fraction of the time it takes to do so using conventional means. The project focuses exclusively on reading; people in the program can acquire a 300–500 word vocabulary in their own language within 30–45 hours spread over 10–12 weeks. The Infosys Foundation (www.infosys.com/infosys_foundation/learning.htm) has set up more than 10,150 libraries in rural schools, as well as well-equipped libraries in Hubli and Bangalore with the latest books in high-tech streams—such as medicine and engineering—that can be accessed by underprivileged students. It has also collaborated with the Center for Environment Education, Bangalore, to train teachers in science and the environment; 15 camps have been held in the 2004–06 period, and 1,000 teachers trained. The Azim Premji Foundation (www.azimpremjifoundation.org) is dedicated to universalizing primary education in India. It works under a Learning Guarantee Program, building a voluntary spirit of accountability among schools, communities, and government functionaries, and studies factors that influence learning. The Byrraju Foundation of Satyam Computer Service broadcasts English and math classes through satellite links and radio towers to more than 200 government-run schools (Corcoran 2006). With IBM's help, it has put computers in 54 rural primary schools and supports vocational programs for plumbers, electricians, and dressmakers. NIIT's Hole in the Wall experiment started in 1999 by introducing a kiosk housing a high-speed, touch-screen computer in a wall in a New Delhi slum, and showed that children can master navigating the Internet within hours (Orvis 2006). Since then, more than 150 computers have been installed in some 50 locations in New Delhi slums and rural India. TARAhaat (www.tarahaat.com) is a franchise network of 37 ICT centers that provide e-education, communication, and governance services to the poor. They also sell innovative products such as fuel-efficient cook stoves, lighting systems, and solar power devices.

Health and preventive medicine. Distance Healthcare Advancement is an initiative of Philips India to deliver high-quality, low-cost diagnostic distance health care for the underserved (www.philips.com/Assets/Downloadablefile/05-DISHA-15354.pdf). It partners with Apollo hospitals, which provides doctors and specialists for free consultations; the Electronics Corporation of India (a government organization that supplies the satellite dish); and with ISRO (Indian Space Research Organization), which places the satellite in orbit.

Linking farmers and the rural population through information technology. Indian Tobacco Company's e-Choupal (www.echoupal.com) is the largest infrastructure network serving villages, farmers, and rural markets, reaching more than 3.5 million farmers in over 31,000 villages through 6,000 kiosks in at least six states. Village Internet kiosks managed by farmers enable the agricultural community to access information in their local languages on the weather and market prices, disseminate knowledge on scientific farm practices and risk management, facilitate the sale of farm inputs, and sell farm produce from the farmers' doorsteps. Real-time information enhances

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Box 4.11 continued

farmers' ability to make decisions and aligns their farm output with market demand and secure quality and productivity. Aggregation of demand for farm inputs gives them access to high-quality inputs from established manufacturers at fair prices. As a direct marketing channel, e-Choupal eliminates wasteful intermediation, significantly reducing transaction costs (Das Gupta 2006). Microsoft's Rural IT Initiative, Saksham (http://www.mission2007.org/saksham_tm.pdf), is aimed at delivering the benefits of IT to rural India. It will partner with Drishtee, Jai Kisan, and n-Logue to roll out kiosks across the country: 50,000 are planned over the next three years. And the Byrraju Foundation has created two IT centers (known as GramIT), with 100 kiosks each in Andhra Pradesh. The foundation covered the initial costs: \$110,000 for computers, wireless networks, and worker training. GramIT withholds some wages for the 1 percent equity that each worker will hold in the local business in two years. It is estimated that each job generates as much revenue as five acres of good land (Corcoran 2006).

Creating opportunities by starting new businesses (www.ifc.org/gbi). The Bharatiya Yuva Shakti Trust (BYST) identifies underprivileged young entrepreneurs and provides them with collateral-free financing over three years. Funding is supplemented by targeted mentoring, monitoring, and networking. BYST has engaged with the Indian corporate sector. Its Mentor Development Program will expand its mentor network to 30,000 over the next five years, affecting 90,000 enterprises run by young entrepreneurs in India.⁵

Source: Authors, based on cited Web sites.

Notes

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1. Such a foundation, the Foundation for Innovation, Research, Support Trial, and Diffusion (FirstD), was discussed during the preparation of the 11th Five-Year Plan for CSIR, according to a communication by Professor Anil Gupta (personal communication July 2006).
2. Karnani (2006) presents a complementary view on how the private sector can help alleviate poverty. Rather than focusing on the poor as consumers, they should be viewed as producers—thereby emphasizing buying from rather than only selling to the poor.
3. Much of the discussion in this section draws on Mathur and Sinha (2006).
4. CSIR is encouraging links between scientists and indigenous knowledge holders. An example is a medicine based on the active ingredient in a plant, *Trichopus zeylanicus*, found in the tropical forests of southwest India and collected by the Kani tribe. Scientists at the Tropical Botanic Garden and Research Institute (TBGRI) collected plant samples, tested the ingredients, and incorporated them into a compound christened Jeevani—giver of life. The tonic is being manufactured by an Ayurvedic drug company. In 1995 an agreement was signed between TBGRI and the tribe to share a license fee and assign 2 percent of net profits to the tribe. This process was perhaps the first time that cash benefits have gone to the source of knowledge of traditional medicines—the original innovators (Mashelkar 2001).

5. Since its inception, BYST has established a network of 3,000 volunteer business mentors and developed more than 1,100 enterprises. Key results over the past 13 years include creation of 10,000 new jobs, 10-fold wealth generation (Rs 10 in enterprise revenue for every Rs 1 invested), counseling of 55,000 young entrepreneurs, 1,000 new jobs a year created by overseas organizations mentored by BYST, and a loan recovery rate of 95 percent (on total loans of \$750,000). Information is from www.ifc.org/gbi.

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Strengthening Skills and Education for Innovation

Isak Froumin, Shanthi Divakaran, Hong Tan, and Yevgeniya Savchenko

More than half of India's population—over 500 million people—are younger than 25. By 2050 India is expected to overtake China as the world's most populous nation, and over the next five years will be responsible for nearly a quarter of the increase in the world's working-age population. Already India has almost a third of the available labor supply in low-cost countries (NASSCOM and McKinsey 2005). These figures, pointing to India's "demographic dividend," represent an enormous competitive advantage for India in its emergence as an innovation economy, and as a potential world-class supplier of skills to the world. However, the widespread perception that India has unlimited employable human resources has changed. India has a growing shortage of skilled workers—caused largely by workforce development and education systems that do not respond adequately to the economy's needs.

To contribute effectively to the innovation economy and capitalize on the growing opportunities of globalization, India's young workforce must develop skills that are more market-driven. Given expanding trade and globalization, India's workforce must have skills that are aligned with its transforming economy and can support the country's continued economic growth. India's ongoing but incomplete transformation from an agriculture- to a manufacturing- and services-based economy requires training a workforce with distinct skills for a market that increasingly rewards problem solving, communication skills, teamwork, and self-learning. Skills are needed not only by high-skill sectors but also by labor-intensive industries, which require technological developments to be absorbed by a workforce adept in basic technological literacy and key competencies.

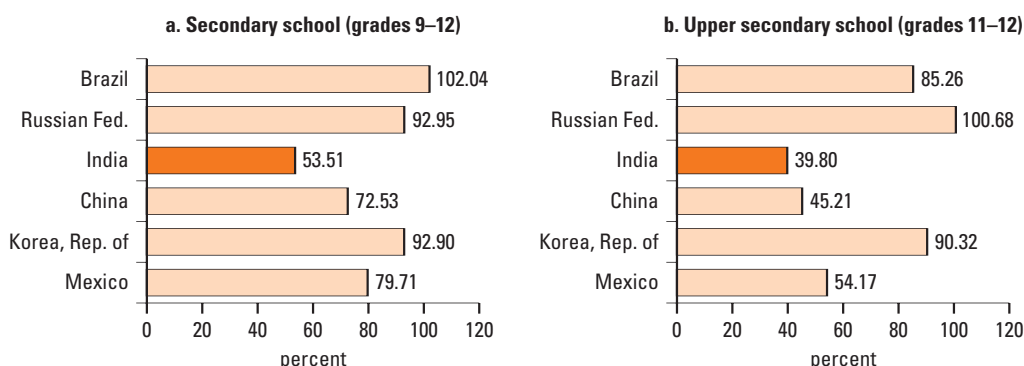
Improving Basic Skills in the Formal and Informal Sectors

Although enrollment in primary schools has increased to 93 percent (Pratham 2007),¹ the quality of primary education continues to be uneven. Since the announcement of the National Policy on Education in 1986, several initiatives have been launched to prepare Indians for the demands of the 21st century. The Sarva Shiksha Abhiyan (Education for All) Movement, for instance, is a government program that seeks to universalize elementary education (grades 1–8) of sufficient quality by 2010. Under this initiative, more than 100,000 new elementary schools have been opened and approximately 500,000 additional teachers have been appointed as of December 2005 (Ministry of Human Resource Development 2006). However, reading, writing, and arithmetic skills remain low among the literate population: 44 percent of students in grades 2–5 in government schools cannot read short paragraphs with short sentences, and 28 percent of students in grade 5 cannot do two-digit subtraction problems (Pratham 2006).²

The quality of education at state-run schools needs to be improved. A Harvard University study found that there were instances of absenteeism and no teaching among primary school teachers: one in four teachers was absent and, of those present, half were not teaching (Kremer and others 2006). Only 40 percent of primary school teachers have college degrees and 30 percent have not completed higher secondary school. Some 72 percent of schools did not have electricity in 2005 (Planning Commission 2006). High student drop-out rates, given such conditions, are not surprising. The average drop-out rate in primary schools was approximately 31 percent in 2003–04 (Planning Commission 2006). Between 1990 and 2002, the average years of education among adult Indians increased only a little—from three years to almost five years—much lower than in East Asian, Latin American, and Organisation for Economic Co-operation and Development countries (Dar 2006: 7). Fewer than 60 percent of children who were born in 1997 and attended grade 1 reached grade 5 (Wu 2006). Regional disparities in education also contribute to India's uneven economic growth—literacy and enrollment rates vary across India, with southern and western states generally faring better than states such as Bihar and others in the north.

Gross enrollment rate³ in secondary schools and the quality of secondary education remain bottlenecks. India continues to have an unbalanced pattern of enrollment growth, with enrollment in secondary education growing insufficiently relative to tertiary education. The gross enrollment rate in upper secondary education (grades 11–12) remains low, at 40 percent (see figure 5.1), despite studies showing the high returns to secondary education, especially for women. Between the early 1990s and 2004, returns to upper secondary school in India rose from 11 to 16 percent and returns to tertiary education from 12 to 19 percent.⁴ The relatively small pool of secondary school graduates creates a bottleneck, impeding the supply of students for tertiary education. Secondary education in India is often of low quality, characterized by rote learning targeted to examinations and outdated curricula that preclude innovative methods of teaching. Although one of the comparative advantages most

Figure 5.1 Gross Enrollment Rates, 2004



Source: World Bank EdStats.

Note: Numbers for Brazil are from 2003 and for Korea from 2005.

commonly mentioned when referring to the Indian workforce is its knowledge of English, most of the population does not gain this skill through the secondary school system. Many secondary schools still rely on an outdated grammar-based approach to teaching English that does not prepare students to communicate effectively in the language. Despite science and mathematics being compulsory for all secondary school students, their proficiency in these subjects is also debatable. Many ninth graders tested in two states using mathematics questions from an international survey had problems with basic arithmetic skills.⁵ Low public funding for secondary education (1.18 percent of GDP in 2003–04⁶) and chronic teacher absenteeism in public schools are also part of the problem. Private schools account for almost 60 percent of the total number of secondary schools but cater to only 25 percent of secondary school students—implying that underfinanced public schools are facing the pressure of absorbing 75 percent of all secondary school students (Planning Commission 2006).

Widespread illiteracy hampers the productivity of the informal sector, despite many programs that serve this sector.⁷ India is home to more than a third of the world's illiterate population (UNESCO 2004), many of whom are part of the informal sector labor force. Currently literacy programs are active in almost all 600 districts in India (Planning Commission 2006). Programs to combat illiteracy, such as through the Jan Shikshan Sansthan (Institute of People's Education), have helped to reduce it: in 2001–02 almost 1.5 million people received literacy training. India's National Literacy Mission,⁸ established in 1988, is aiming for 75 percent national literacy by 2007. But the official literacy rate is still low at 62 percent.⁹ In India this translates to roughly 400 million illiterate people. Some even argue that the 62 percent includes people who are functionally illiterate and can only write their names (*Economist* 2006).

The lack of basic skills also limits the capacity of the informal sector, and while several programs catering to this sector exist, few address the issues of the informal sector adequately. Public training institutions do not play a significant role in

addressing the informal sector—only 12 percent of Industrial Training Institute graduates, for instance, are part of the informal sector. However, a host of other programs and institutions are devoted to this sector. For instance, 675 community polytechnic institutes have been set up with a focus on the informal sector, training about 450,000 people in communities through three- to nine-month courses. Other programs include the Jan Shikshan Sansthan and National Institute of Open Schooling, which offer opportunities to the informal sector through vocational courses and basic education programs. Programs for the informal sector are also administered by other players, including the Ministry of Rural Areas and Employment, Ministry of Small Scale Industries, Department of Women and Child Development, and Bharatiya Yuva Shakti Trust.

However, the multidimensional skill set required by the informal sector, encompassing both technical and business management skills, is not adequately provided for by most formal training programs for the sector. Even apprenticeships, the predominant training program for the informal sector, while flexible and self-regulating, are limited in exposing trainees to modern technology and innovative practices. Many workers in the informal sector are also held back by their lack of basic education, which reduces their ability to absorb the information provided by some of these programs. Finally, although 89 percent of Indian workers are employed by the informal sector, the resources devoted to enhancing their skills do not reflect this reality. In 2003–04, for instance, public expenditure on adult education continued to remain low at 0.02 percent of GDP.¹⁰

The lack of adequate basic skills in the formal and informal sectors directly impacts the potential of the innovation economy. High illiteracy limits the population's capacity to acquire the basic skills needed for an innovation economy and curbs the productivity potential of the informal and lower-skill sectors. Technological literacy and access to information and communication technology (ICT) resources are also important at the foundational level if India is to continue to capitalize on its strength in information technology-related industries. If adequate skills are not imparted at the foundational level, whether through the formal or informal educational systems, there will be fewer qualified workers in labor-intensive industries and a reduction in the availability of skilled workers for the innovation system as a whole. Moreover, low workforce education levels are significantly correlated to low firm productivity—increasing the average education level of a firm's workforce by one year is associated with a 13–16 percent increase in firm productivity.¹¹

Recommendations for Strengthening Basic Skills

To improve basic skills in the formal and informal sectors, the government should undertake the following two reforms:

1. *Use innovative approaches to improve the quality of primary and secondary education.* The government should revamp the primary and secondary education systems by modernizing curricula and creating a more flexible, responsive education

system. Efforts should also be made to introduce television campaigns, national competitions, and summer schools to promote project activities and excellence in public secondary schools. ICT literacy must be given greater prominence in the early years of education to sufficiently prepare students for an increasingly ICT-dominated world. To contend with high drop-out rates, programs such as the Mid-Day Meal Scheme, which can increase student attendance in school, must be strengthened. Teachers must be trained adequately and given sufficient incentives so that teacher vacancies decrease and accountability and motivation increase. The quality of education at primary and secondary schools must be regularly monitored by independent testing bodies (Planning Commission 2006). New approaches also must be experimented with to address existing problems.

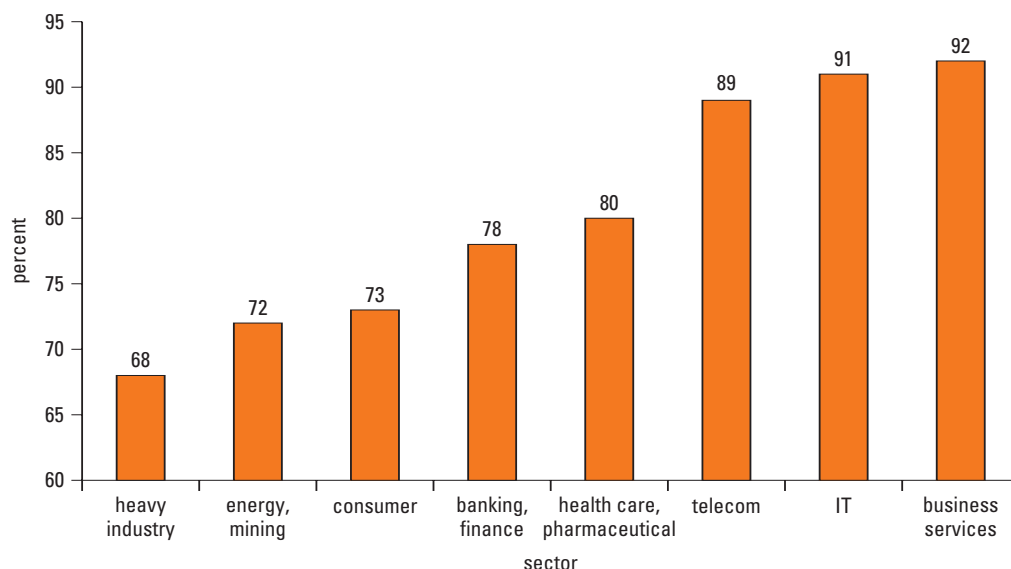
2. *Strengthen basic skills for the informal sector, including functional literacy.* The government should continue to invest in programs that combat illiteracy and help transfer skills to the informal sector by supporting local nongovernmental organizations (NGOs) that provide adequate training to meet the needs of the informal economy. Efforts should include training instructors, developing curricula, and providing financial incentives to encourage external financing of informal-sector training programs. In addition, the government should provide regulatory and financial support for informal education through focused, short-term courses and programs—such as training in information technology (IT) literacy. Innovative ideas should also be considered: for instance, paying workers to attend classes, to compensate for lost wages.¹² Doing so could provide sufficient incentives for workers to attend training programs.

Building a More Skilled Workforce: Enterprise-Based Training and Vocational Education

The shortage of skilled labor in India in the IT and financial sectors is also being experienced by the manufacturing sector. With average annual economic growth of over 8 percent and booming growth in many sectors, it is no surprise that India's education and workforce development system is struggling to respond to rapid growth in the demand for skilled labor. The shortage of skilled labor for the IT industry is well known: although the country produces nearly 400,000 engineers a year, NASSCOM predicts that its IT sector will be short 500,000 professionals by 2010 (NASSCOM and McKinsey 2005).

However, the shortage of skilled workers is not limited to IT: it cuts across sectors and poses a serious hindrance to India's growing economy (figure 5.2). Termed the "Bangalore Bug," the skills scarcity faced by the booming IT and financial services industries is spilling over to other industries, including those that employ less-skilled workers. Recent studies show that the manufacturing sector is losing skilled workers to more knowledge-intensive sectors, and that the increasing affluence of the skilled segments may impede the dynamism of enterprises that employ the unskilled and less well educated (Kocchar and others 2006). Such an

Figure 5.2 Business Executives with Companies Headquartered in India Respond to Future Skills Constraints in Their Sectors



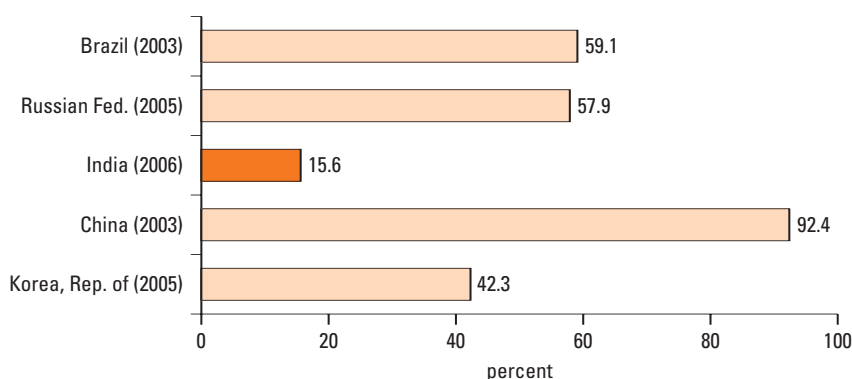
Source: McKinsey 2005.

Note: Global business executives numbering 537 answered the question, "Will talent be a significant constraint on the growth of your company during the next 5 years?"

environment leads to increased poaching between industries due to the dearth of talent (Rajan and Subramanian 2006). The advertising industry, for instance, has seen high attrition rates—particularly among senior and middle managers, who are being recruited into sectors such as telecommunications and retail (Srinivasan 2006).

The fastest-growing Indian states and most innovative Indian firms face the most severe shortages of qualified staff. Although the manufacturing enterprises surveyed in the India 2006 Enterprise Survey, on average, did not rank skills and education of available workers among their top five most severe constraints to operations and growth, firms in India's faster-growing regions did. Firms in Maharashtra, Gujarat, and Tamil Nadu cited skills and education as more binding constraints than did those in laggard states.¹³ These highly productive states have grown rapidly because of increasing specialization in high skill-based services such as IT, finance, telecommunications, and skill-based manufacturing such as petrochemicals and pharmaceuticals. Thus, it is not surprising that skills and education would be considered important requirements for their firms to maintain a competitive edge. According to the India 2006 Enterprise Survey, firms that innovate consider lack of skilled workers a bigger impediment to growth (17 percent) than those that do not (11 percent).¹⁴

Indian employers' underinvestment in worker training, relative to their counterparts in other fast-growing economies, places the country at a competitive disadvantage. A firm's capacity to create or absorb knowledge depends on the skills and

Figure 5.3 Manufacturing Firms Offering In-Service Training

Source: World Bank Enterprise Surveys.

training of its workforce. Yet only 16 percent of Indian manufacturing firms provide in-service training to their employees (figure 5.3). This investment in training is low compared with fast-growing East Asian economies such as the Republic of Korea (42 percent) and China (92 percent). The low level of in-service training in India results from several factors (Batra and Stone 2004):

- Most firms not providing training identified the technologies they were using as “mature,” and so did not require training or skills upgrading to use new technology.
- Many firms said that training was unaffordable because of limited funding resources, suggesting a weakness in financial markets.
- Many alluded to the high turnover of trained staff, which prevents them from recouping the costs of training employees.
- Many employers pointed out that informal on-the-job training was adequate or that skilled workers were readily available. Both reasons are suggestive of low skill requirements, possibly from the use of mature technologies.

Studies suggest that firms’ capacity to innovate and absorb new technology and to benefit from innovation and adoption depends critically on worker skills and training (see Bell and Pavitt 1992). India’s underinvestment in in-service training thus severely constrains firms’ capacity to innovate.

Empirical analysis suggests that innovative firms invest more in in-service training and that firms that provide formal in-service training are more productive. The share of firms that provide in-service training is significantly correlated with innovation along several dimensions—firm size, industry, whether the firm engages in research and development (R&D), export status, foreign ownership—suggesting the following¹⁵:

- Larger firms are more likely to provide training than smaller firms, and to rely on in-house training rather than external training institutions, whether public or private.

- Firms in technology-intensive industries—such as automotive components, drugs and pharmaceuticals, and machinery—are more likely to provide in-service training.
- Firms that conduct R&D have a three-times-higher incidence of training than those that do not.
- Export orientation can have a salutary effect on training that produces high-quality products meeting the exacting standards of foreign buyers, and that increases labor productivity to meet competitive pressures (Tan and Batra 1995).
- Firms with foreign equity (possibly because of their embodied foreign technology and know-how) are more likely to provide training than domestic firms.

A key question is whether innovation is possible without a highly skilled and trained workforce. A bivariate probit model was jointly estimated for the decision of whether to innovate and the decision of whether to train. The results suggest that innovating firms tend to be larger, are managed by more educated general managers, employ a more educated workforce, and export; and that firms that train are larger, have some foreign ownership, and export. Most important, the correlation between the two equations is positive and statistically significant, confirming that firms' training and innovation decisions are made jointly (technical appendix table A.5). Finally, the India 2006 Enterprise Survey allows an econometric assessment of the productivity effects of training. Firms that provide in-service training are 23–28 percent more productive than firms that do not.¹⁶

India's vocational education and training system needs to be better aligned to market needs to meet the preservice training requirements of enterprises. Vocational education and training are distinct streams in India, with vocational education provided as part of the upper secondary school system (grades 11–12) and vocational training provided outside the formal schooling system. However, the relevance and quality of these vocational education training programs are questionable. Only 3 percent of rural youth and 6 percent of urban youth have been vocationally trained (Planning Commission 2006). Fewer than 3 percent of students in grades 11–12 are enrolled in vocational education, and students who enter vocational education programs are believed to be those who performed poorly in 10th grade. Of these, most graduates pursue further education, reinforcing the insignificance of secondary school programs. The irrelevance of these programs to market needs can partly be explained by the lack of private sector involvement in running vocational education and training programs. Although the government seems eager to expand the vocational education system, it is not clear that such an expansion would be useful given the irrelevance of current courses to the labor market and the market's increasing trend to reward general rather than specialized skills (Dar 2006).

Outside the formal schooling system, the main vocational educational program is the Craftsmen Training Scheme, which operates through 1,895 government Industrial Training Institutions that enroll 400,000 students and 3,358 private Industrial Training Centers that train 340,000 students. These institutions are accredited by

government agencies and provide programs lasting from six months to three years. Vocational training is also provided at the tertiary level, varying in duration from one to three years. But the India 2006 Enterprise Survey found that the training offered by external providers of vocational education and training, public and private, does not contribute to higher enterprise productivity. Besides the uncertain quality of the education offered at these institutes, there is not enough information about the effectiveness of vocational training programs due to a lack of evaluation at both the central and state levels. The government also does not have enough information about private providers of vocational education and training, which could mean that private players are being crowded out by the public sector.

In addition, apprenticeship training programs are administered by the Ministry of Human Resource Development and the Directorate General of Employment and Training under the Ministry of Labour and Employment. But only 158,000 apprentices were trained through these programs in 2001, and most are focused on engineering (Dar 2006). Besides, a 2003 study of graduates in apprenticeship training programs found that these training programs were not relevant to the labor market.¹⁷

Better management and supervision skills are also needed to deal with India's fast-track technological environment, which requires skills channeled toward higher productivity. Good management is required not only in skill-intensive sectors but also in the labor-intensive, unskilled manufacturing sector. Management has a critical role to play in modernizing the labor-intensive sector, especially in less-developed Indian states. Successful technology absorption, for instance, is possible only if managers and supervisors in service firms and industry are willing to introduce new technologies and organizational innovations and have appropriate skills. Good managers should recognize the need for in-service training and for appropriate incentives to motivate employees to generate innovative ideas. The growing modernization of the manufacturing sector will increase the demand for well-educated, trained workers and technicians as well as managers. Although international business leaders rank the quality of Indian management schools very high,¹⁸ a small number of excellent Indian Institutes of Management and other Indian business schools cannot supply sufficient managers—especially for small and medium enterprises (SMEs). And current innovative programs, such as for Masters of Small Business Administration, are insufficient to fill the informal sector's need for entrepreneurship skills.

Recommendations for Building Worker and Manager Skills

There are three important recommendations for building worker and management skills. They are the following:

1. *Strengthen enterprise-based training.* The government should help ensure that the benefits of in-service training are widely recognized by enterprises, while simultaneously providing strong financial incentives—such as matching funds—for firms that invest in training. Existing SME-targeted training programs should be evaluated, and improvements in program design, such as payroll levy training

Box 5.1 Malaysia's Human Resource Development Fund

Malaysia established the Human Resource Development Fund (HRDF) in 1993 to promote enterprise-based training among firms—first in manufacturing and more recently in services. HRDF schemes are administered by a council, with representatives from the private sector and various government agencies, and a secretariat. Eligible employers with 50 or more employees are required to contribute 1 percent of payroll to the fund, making them eligible to claim training funding up to the limit of their levy payments in any given year. The HRDF council sets rates of reimbursement, varying by type of training and size of firm (rates are higher for smaller firms). The HRDF also requires firms to spend a minimum amount on training or lose their levy contributions, creating incentives for firms to train rather than poach skilled workers from other employers.

The HRDF offers different schemes that give employers flexibility in training in-house or using public and private providers, including second-tier public-private intermediaries such as state-level skill development centers. HRDF funding has created a vibrant training market, with public and private providers competing for resources. It addresses information constraints through public information campaigns, subsidized delivery of training need assessments for SMEs, certification of training providers and wide dissemination of their offerings, and electronic billing to keep employers informed of their levy use status. Recognizing the funding constraints of SMEs, the HRDF council enlists certified providers to act as its agents, collecting from users the fees for which firms are responsible and claiming the reimbursable balance from the HRDF, thus reducing up-front cash outlays for SMEs.

Source: Tan 2005.

funds and matching grants (Malaysia Human Resource Development Fund, for instance; box 5.1), should be considered. Financial incentives should be provided to employers that encourage worker training (Dar 2006: viii). And based on results, enterprise-based training should be expanded at the national level.

2. *Improve vocational training.* India's vocational education and training systems have thus far been unsuccessful in preparing graduates to meet market needs, particularly because of a lack of interaction with industry. Aligning these systems with market needs requires restructuring—including private participation—in the management of institutions, curriculum development, and system financing; upgrading infrastructure and instructor capabilities; stronger performance incentives for vocational education and training institutions; and regulatory reform to give training institutions greater autonomy to respond to market skill needs and incentives, to change course offerings, and both charge and retain fees. The abilities of public and private vocational education and training providers should be strengthened to make them more responsive to demand in their offerings. Curricula should be updated to reflect modern technologies and improve flexibility by mapping the supply of and demand for skills and by ensuring that the private sector is involved in curriculum design (Dar 2006).

Incentives should be in place for public-private partnerships to provide vocational education and training. Certification programs that provide a signal of candidate quality would also be helpful. The government, working with the World Bank, has recently launched initiatives to address these issues and improve vocational training.

3. *Strengthen business and management education, including the management of research and commercialization.* Business and management education should be strengthened through public-private partnerships. Innovative management courses should be introduced in engineering and science education through a strong policy push from center (from the All India Council for Technical Education and other quality assurance and accreditation bodies). To strengthen grassroots innovation skills, skills upgrading programs should be matched with technology transfer programs—possibly through small grants for small-scale technology projects involving universities. Stronger incentives are needed to strengthen the entrepreneurial culture at universities and colleges by involving students and professors in real businesses.

Strengthening Engineer and Researcher Skills: Transferring Market-Relevant Skills in Higher Education

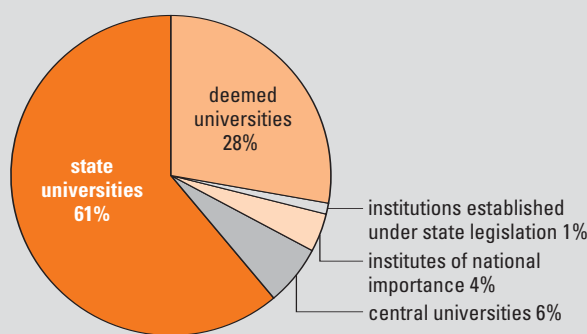
India's demand for highly educated and skilled knowledge workers outstrips the supply. The high demand is fueled partly by India's popularity as an R&D destination for multinational corporations luring away domestic talent, and partly by the blossoming of India's IT and IT-enabled services sectors.¹⁹ The higher education system's ability to contend with the supply constraint will thus play a major role in India's competitiveness as a knowledge economy.

Universities are the cradle for sustained creativity and innovation. Yet despite the global standing of several Indian institutions of higher learning, the higher education system's output is uneven. India's higher education system has two subsystems: excellent institutions, such as the Indian Institutes of Technology (IITs), Management (IIMs), and Science (IISc); and second-tier and other institutions. Excellent institutions, however, are few compared to the multitude of institutions that make up India's large higher education system (box 5.2). Since independence, the number of Indian universities has increased by a factor of 13, the number of colleges by a factor of 24, and enrollment by more than a factor of 10. Selectivity at the top-tier institutions is extremely rigorous. Acceptance rates at IITs are approximately 3 percent. While the seven Indian Institutes of Technology churn out just 3,000 graduates annually, the second tier had 207,000 graduates in 2005 (Puliyenthuruthel 2005). Second-tier institutions, with 2,240 engineering colleges, of which 45 percent are privately managed, are increasingly supporting the growing need for engineers. However, quality training continues to concentrate in "islands of excellence": 80 percent of doctorates in engineering are awarded by 20 leading institutions, while 65 percent of doctorates in sciences come from 30 leading institutions. In addition, rigid curriculum policies and

Box 5.2 India's Higher Education System

- As of March 2006, India had 355 universities and 18,064 colleges.
- An estimated 11 million students were enrolled in the higher education system, taught by approximately half a million faculty.
- Maharashtra had the highest enrollment of students in higher education (1.5 million), followed by Uttar Pradesh (1.4 million).
- Sikkim had the lowest enrollment (less than 5,000).

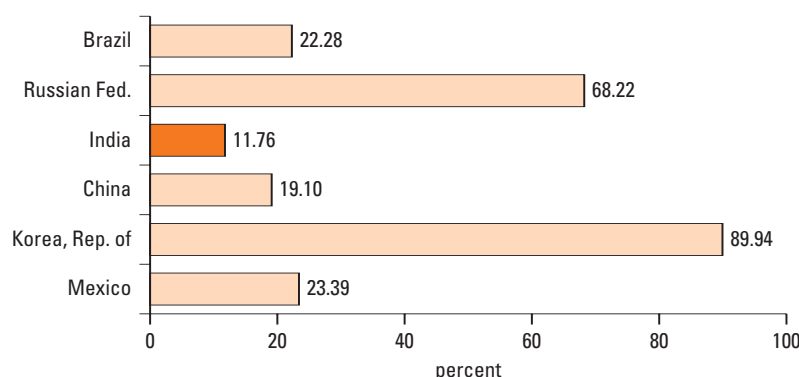
**Types of universities in India
(total of 355 as of March 2006)**



Source: University Grants Commission 2006.

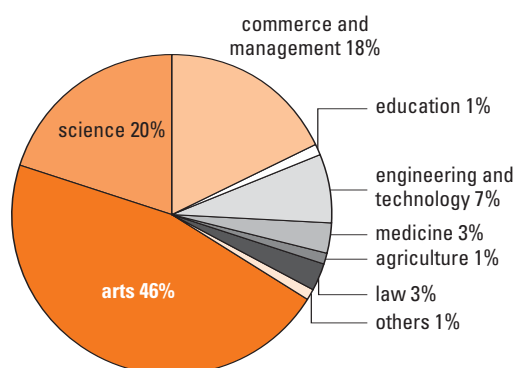
lack of incentives for professors and institutions to modernize curricula lead to limited innovation in the education system. There is also a severe faculty constraint in academic institutions: 20–30 percent of lecturer and professor positions are vacant. Universities have found it hard to retain good faculty, given the high increase in private sector salaries. In an educational system of such uneven quality, competitive entrance examinations have thus replaced university performance as signals of candidate suitability for higher education and jobs (Kapur and Mehta 2004).

The lack of skilled researchers and knowledge creators is manifested in low output of high-quality research. Most research output from Indian institutions, such as patents and publications, has been lackluster. As the scientific advisor to the prime minister recently wrote, research from Indian universities is “hitting an all-time low. They are unable to perform and compete.”²⁰ While China produces 8,000 engineering and science doctorates a year, India generated 6,617 such degrees in 2004–05.²¹ Of the 17,898 doctoral degrees awarded by various universities during 2004–05, the faculty of arts led with 7,532 degrees. Enrollment in tertiary education in general is low (12 percent) when compared with other countries (see figure 5.4) and a large number of students are enrolled in disciplines that traditionally have weak links to the job market (figure 5.5).

Figure 5.4 Gross Enrollment Ratio, Tertiary Education

Source: World Bank EdStats.

Note: Numbers for Brazil are 2003 and for Korea are 2005.

Figure 5.5 Student Enrollment in Higher Education, 2005–06

Source: University Grants Commission 2006.

India also has not done a good job of retaining its best researchers. Graduates from elite science and technology institutions tend to go abroad for postgraduate study, leaving half of the elite universities with postgraduate programs to accept undergraduates from less-prestigious institutions who have not been trained in highly demanding programs. Most undergraduate colleges do not include research in students' academic requirements, limiting their ability to conduct research at the graduate level. Thus, it is not surprising that only a third of science graduates pursue occupations related to their formal educational qualifications. Although Indians are open to the benefits of science and technology, surveys show that the share of students who want to study pure science at higher levels of education falls from 22 percent in grade 6 to 13 percent in grade 12 (NCAER 2005). The education system is thus not motivating students to pursue careers in science and technology.

Weak links with industry create a mismatch between market needs and worker skills. In absolute numbers, India's output from its higher education system is high—in 2006, 11 million students were enrolled in the higher education system. However,

Box 5.3 Training Offered by the Private Sector in India

Certain players in India's private sector have tried to correct the misalignment in skills provided through the education system and strengthen the skills required for competence in the workforce. These initiatives are probably most pronounced in the IT sector. Players such as Infosys, Tata Consultancy, Wipro, and Satyam Computer Services, which hired a total of 40,000 engineers in 2004, have collaborated with universities to supply course materials and train lecturers on developments in topics most relevant to their business—such as chip design and radio frequency identification. Although these collaborations require investments from the private firms, they pay off almost immediately, because graduates from colleges that partner with these companies require shorter in-house training once hired. For instance, over three years Tata Consultancy reduced its training program from 76 to 52 days as a result of these training collaborations.

Source: Puliyyenthuruthel 2005.

McKinsey studies show that only 10–25 percent of general college graduates in India are suitable for employment (Farrell, Kaka, and Sturze 2005). India is likely producing many graduates whose skill sets make them unemployable. One of the main reasons is that links with industry are low in most education institutions, leading to curricula that do not reflect modern technological developments and do not include industrial practices. Universities update training programs without real involvement from advanced industry or the R&D sector. Moreover, since the 1970s university students have not been required to train or do project work in conjunction with industry—leading to student projects being prepared in laboratories that do not reflect existing conditions of technology use. Some initiatives have collaborated with the private sector to correct the labor market mismatch with India's education system. The government's Mission REACH program is creating Centers of Relevance and Excellence in a network of universities to strengthen industry-university links in a diverse set of disciplines. The program's mandate is to produce top-quality graduates with skills directly relevant to industry needs.²² Similarly, companies like Infosys, Tata Consultancy, and Wipro provide course materials to some institutions and train teachers, enabling them to invest in shorter training times for their employees (box 5.3) (Puliyyenthuruthel 2005). However, such initiatives are not representative of the majority of India's higher education institutions.

Rigid centralized control of the education system leads to insufficient capacity for higher education institutions to be innovative and responsive to the needs of students or the labor market. The University Grants Commission is the central body that funds government-recognized universities and colleges and provides accreditation for higher learning through 12 autonomous institutions. Heavy regulation of India's higher education system has limited the ability of institutions to innovate in their curricula, leading to a widely held perception that the system encourages

rote learning rather than creativity or self-learning. Public institutions have not, for instance, been allowed to mobilize private funds (Kapur and Mehta 2004). Universities have low fiscal, managerial, and curriculum autonomy.²³ There also is insufficient industry involvement in governing the education system and institutions.

Low public funding for higher education institutions has constrained their ability to offer quality education. For many years, financing of higher education has been the responsibility of the central and state governments. The central government provides only 25 percent of public financing for higher education; the rest comes from states. Public spending on higher education is low, at approximately 0.7 percent of GDP.²⁴ Moreover, India provides free education to a relatively large number of students, leading to underfinanced higher education programs. Spending on higher education is estimated to be about 40 percent less than the desired level (Agarwal 2006). This shortage affects the quality of education. The deficit cannot be filled by the government alone—innovative solutions are needed to bring in private funds.

Although the private sector has become active in providing higher education, the quality of private institutions varies, and too much regulation makes private players reluctant to invest enough in education. About half of higher education spending is borne by private sources. Although in many countries private higher education has grown in “soft” areas such as humanities, economics, management, and law, in India the private sector has moved to “hard” professional areas. For example, about 85 percent of undergraduate engineering education is under private management. One of the most dynamic parts of private participation is exam preparation courses (private tutoring). Between 20 and 40 percent of applicants for higher education use private preparation courses.

Private players must surmount significant entry barriers posed by regulatory controls. To grant degrees, private colleges have to be affiliated with state universities, unless they are “deemed” universities. Private colleges are guided by some of the same curriculum restrictions that confine public ones (Kapur and Mehta 2004). In the past, entry barriers were also high for foreign universities, though a November 2006 government agreement to clear foreign direct investment (FDI) in higher education and allow foreign universities to set up campuses in India is a positive initiative. Every year 100,000 Indian students leave to attend foreign universities, at an average annual cost of \$4 billion (Lakshman 2006). Allowing foreign universities to set up shop in India could both curb the brain drain and save money for many Indian families. It could also help transform India into a global platform for supplying quality education.

Recommendations for Making Higher Education More Relevant to Market Needs

There are two recommendations for promoting the relevance of higher education to market needs. They are the following:

1. *Increase private participation in higher education.* To address the growing supply constraint of high-quality education institutions, India’s higher education system

needs stronger incentives to attract domestic and foreign private participation in higher education and its financing. Private institutions must be able to charge reasonable fees if they are to be encouraged to invest in education. The November 2006 government agreement to allow both FDI in higher education and foreign universities to set up campuses in India is an appropriate step in this direction. Stronger incentives are also needed for private provision and financing of formal and informal education—in particular, encouraging large corporations to establish new universities through public-private partnerships.

2. *Increase fiscal and managerial autonomy of universities and colleges.* An increase in joint training programs with industry—including courses such as small business administration programs for SMEs—would help ensure that university curricula reflect market needs. Joint in-service training programs with university participation should be promoted, possibly through matching grants (to strengthen links with industry). Competitive grant programs for academic innovations and performance-based incentives for professors would also foster a more vibrant academic environment better aligned with the dynamic growth in India's knowledge-intensive sectors. Selected higher education institutions should be upgraded to the highest levels, coupled with the provision of competitive grant programs for academic innovations and the introduction of joint training programs with industry and with top foreign universities and multinational corporations. Systematic analysis of qualification exams should be conducted to review the performance of higher education institutions. In addition, the quality of higher education faculty should be improved by using leading institutions as training centers for other faculty, introducing more performance-based incentives for professors, and expanding grant programs for mobility between professors and industry. Efforts should also be made to move to systemwide quality improvement, with a goal of two or three leading universities in each state. Finally, a national testing system should be established to ensure high, uniform performance standards for higher education graduates.

Notes

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1. This number refers to net primary enrollment rate, or the number of pupils in the theoretical age group for primary education enrolled in primary education as a percentage of the total population in that age group.
2. Figures for private schools are not much better.
3. Gross enrollment rate is defined as the total enrollment in a specific level of education (regardless of age) as a percentage of the official school-age population corresponding to the same level of education in a given school year.
4. Riboud, Savchenko, and Tan (2006) used earnings data from two decades of household surveys in India to estimate the private returns to an additional year of schooling, and how returns have changed for different educational groups.

5. According to the TIMSS (Trends in International Mathematics and Science Study) survey. See Wu (2006).
6. Selected Educational Statistics 2003–04, Ministry of Human Resource Development.
7. This section is drawn from Dar (2006).
8. The program aims to provide functional literacy to nonliterates in the age group 15–35 through its principal strategy, the Total Literacy Campaign.
9. World Bank, EdStats, September 2006, <http://devdata.worldbank.org/edstats/>.
10. Department of Elementary Education and Literacy: Proposed Scheme-wise Break-up of Annual Plan Allocation for 2005–06.
11. Based on 2006 India Enterprise Survey analysis. See technical appendix table A.6.
12. Conversation with Mr. Jawahar Sircar, Additional Secretary and Deputy Commissioner, Ministry of Small Scale Industries, December 2006.
13. According to the India 2006 Enterprise Survey, the proportion of manufacturing firms indicating that skills and education of workers are a major or severe constraint to business and operation is 26.2 percent for Tamil Nadu, 18.3 percent for Maharashtra, and 17.3 percent for Gujarat, versus 13.6 percent for Bihar, 13.3 percent for Uttar Pradesh, and 10.5 percent for Rajasthan.
14. For this finding, an “innovative” firm is defined as having positive spending on R&D, on royalties or license fees, or having acquired new technology.
15. See technical appendix table A.4.
16. See technical appendix table A.6. This finding is consistent with other cross-sectional studies that have found a strong positive association between in-service training and productivity and wage levels of firms (Batra and Stone 2004; Tan and Batra 1995), and panel studies that have found evidence that training, especially when repeated, leads to higher productivity growth and wages (Tan 2005 for Malaysia; Tan and Lopez-Acevedo 2003 for Mexico).
17. Dar (2006), referring to the study by the Directorate General of Employment and Training.
18. See, for instance, World Economic Forum (2006).
19. According to Global Sourcing Now, the global knowledge process outsourcing industry is expected to reach \$17 billion by 2010, of which \$12 billion would go to India.
20. C. N. R. Rao in a letter to the prime minister, in Seethalakshmi and Seshagiri (2006).
21. University Grants Commission Annual Report, 2005–06.
22. <http://www.missionreach.org>.
23. C. N. R. Rao in a letter to the prime minister, in Seethalakshmi and Seshagiri (2006).
24. Ministry of Human Resource and Development, Selected Educational Statistics 2003–04.

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Upgrading Information Infrastructure

Shanthi Divakaran, Anil Srivastava, and Mark Williams

Obtaining and applying information lies at the heart of the innovation process. Thus, the availability of information is a key driver of firms' ability to create and absorb new ideas. The creation of ideas and dissemination of ideas between firms and countries are strongly influenced by the availability of information, the cost of obtaining it, and the ease of sharing it. Electronic communication systems are at the center of this information transfer process, so investment in information and communication technology (ICT) infrastructure is one way of stimulating growth in national innovation and economic productivity. International evidence shows a clear link between investment in ICT and productivity (Röller and Waverman 2001; Qiang and Pitt 2004). At the firm level, research shows that use of ICT can result in higher productivity and profitability. A recent World Bank study concluded that "enterprises that use ICT more intensively are more productive, grow faster, invest more, and are more profitable" (Qiang, Clarke, and Halewood 2006: 57).

India's ICT sector has progressed rapidly—but challenges remain if it is to continue to create and enable innovation. India's ICT sector has grown quickly over the past 20 years, but this growth must continue and reach all segments of the economy to fully support the development of an innovation economy. To achieve this, the government must address a number of policy and regulatory issues to ensure the sector's continued growth and its extension into underserved areas.

The availability and quality of ICT infrastructure accessible by research institutes will be increasingly important in fostering innovation. Collaboration between universities and research institutes—both within and outside India—requires investment in high-speed communications networks.

Improving Access to ICT Infrastructure

The use of basic ICT infrastructure and services is a key enabler of innovation in all types of firms. The availability of ICT services is an important determinant of businesses' ability to innovate and develop new ways of organizing. This applies across the entire range of businesses, from large enterprises investing in IT-based reorganization to micro and small enterprises using ICT to change how they do business. Studies of demand for telecommunications services in developing countries indicate that telephones are often used in basic economic activities, such as seeking information on input and output prices, employment opportunities, and so on.

ICT-based exports are becoming increasingly important in India. The ICT industry has grown quickly through innovations in products, services, and business practices. Over the past 15 years India's services sector has become an important contributor to economic growth. In 2004 India was ranked 30th in the world in total exports, but 9th in exports of services (excluding travel and transportation),¹ accounting for 3 percent of the global total. Communications and business services have made major contributions to this growth (table 6.1).

Over the past 10 years, growth in the IT services industry has been boosted by the global increase in offshoring IT- and IT-enabled services (ITES, such as business process outsourcing). By 2005 turnover of this industry had reached \$22 billion in India (Purfield and Schiff 2006), with software and business process outsourcing accounting for about a third of service exports. India leads the world in the supply of business process services, with two-thirds of the global offshore IT industry and 46 percent of the global offshore business process industry (NASSCOM and McKinsey 2005: 56).

ICT and ITES have been a major source of innovation in the Indian economy. The IT industry was originally based on import substitution, then low-skill computer programming. However, since then, innovation in business practices and technology has stimulated the evolution of the industry. The model of sending

Table 6.1 Average Annual Growth of Value Added in Communications and Business Services in India, 1950s–2000s

(percent)

Sector	1950s–70s (share of 1980 GDP)	1980s (share of 1990 GDP)	1990s (share of 2000 GDP)	2000s (share of 2004 GDP)
Communications services ^a	6.7 (1.0)	6.1 (1.0)	14.9 (2.2)	24.4 (4.3)
Business services ^b	4.2 (0.2)	13.5 (0.3)	19.8 (1.1)	20.7 (1.8)

Source: Purfield and Schiff 2006.

a. Includes, among others, postal services, money orders, telegrams, telephones, and overseas communications services.

b. Software and business process outsourcing.

Table 6.2 IT-Enabled Services and Business Process Outsourcing Revenues and Employment in India, by Service Line, 2003–04

Service line	Employment	Revenues (\$ millions)
Customer care	95,000	1,200
Finance	40,000	820
Human resources	3,000	70
Payment services	21,000	430
Administration	40,000	540
Content development	46,000	520
Total	245,000	3,580

Source: Athreye (2005) estimates based on data from the National Association of Software and Service Companies.

teams of software engineers to client sites to conduct projects originated in India, and the more recent shift toward exporting offshored office services are major innovations made possible by the development of India's ICT industry. The adoption of new ways of doing business and the use of new technologies to carry out functions previously done onshore have transformed India's export sector—and this process is continuing, resulting in the offshoring industry in India servicing a wide range of markets (table 6.2).

Innovation in IT and ITES continues—and is increasingly at the higher end of the value chain. The offshore revolution in India has not stopped with software maintenance and call centers. ICT services increasingly facilitate the location of high-end, innovative economic activity in the country. Not only are there huge untapped areas in services already offshored, further growth opportunities are opening up as high-risk and complex service lines are also offshored. For example, the John F. Welch Technology Center in Bangalore is conducting advanced research and development (R&D) in technologies such as advanced propulsion systems for aircraft engines and contributed significantly to the design of General Electric's latest jet engine. This is not all. The market can be further expanded by innovations in service delivery allowing the creation of "offshore-only" processes, for example, to stem the big "value slippages" facing industries. A leading U.S. bank has saved \$100 million through offshore detection of fraud in low-value transactions. Offshoring has also allowed banks to create new services (for example, subprime lending for previously unviable customer segments) (NASSCOM and McKinsey 2005: 56). This type of innovation by large, export-oriented businesses depends on high-quality ICT infrastructure. As this sector grows, the availability, quality, and price of ICT infrastructure will become increasingly important for the Indian economy.

Basic ICT infrastructure and services also have a significant impact on innovation and productivity in households and small businesses. Households and small enterprises use ICT services to improve the organization and marketing of their economic

activities. Thus, investment in ICT services (such as mobile handsets) is investment in productive assets that have the potential to raise household and firm incomes. Box 6.1 describes a study that quantified the economic impact of mobile phones in Kerala, India.

In rural areas there are few alternatives to ICT as a means of communicating. Those alternatives—such as sending a person, using mail, or calling from somewhere

Box 6.1 The Impact of ICT on Small-Scale Fishing Enterprises in Kerala

The fishing industry is an important part of life in the state of Kerala. More than 70 percent of adults eat fish at least once a day, and over 1 million people work in fisheries. Fishing is done primarily by small enterprises, working near home markets and traditionally selling their catches to a specific market. Fishermen have traditionally been unable to observe prices in other markets along the coast because of high transport costs and ineffective communications. There is little storage of fish because of costs and little transportation of fish over land and between markets because road quality is poor and refrigeration is not available. Thus, the quantity of fish sold in any market is determined by the local catch, which also determines the prices that fishermen receive for their catches and the prices that customers pay. This dislocation of markets results in significant differences in the price of fish on any given day between markets that are quite close to each other. It also results in wasted catches because there are occasions, when there are large catches, where there are not enough buyers.

Mobile phone services were introduced in Kerala in 1997. As in other parts of the world, mobile networks were initially concentrated in cities and towns. However, because many cities in Kerala are located along the coast, mobile network coverage extends 20–25 kilometers out to sea—the distance within which most fishing is done. Fishermen adopted mobile phones very quickly, reaching an equilibrium penetration rate of 60–75 percent (compared with an average rate of 5 percent across the region). Fishermen use the phones while still at sea to find out the prices in different markets and to decide where to land their catches. Fishermen typically call several markets and agree on a price before landing their fish, effectively conducting auctions by phone.

The effects have been dramatic. After mobile phones were introduced, 30–40 percent of fishermen began selling fish outside their home markets, compared with almost none beforehand. Within a few weeks this significantly reduced the dispersion in fish prices between markets. Prices on any given day now rarely differ by more than a few rupees per kilogram, compared with up to 10 rupees per kilogram before. Moreover, there are no cases of wastage. The use of mobile phones has also boosted incomes for fishermen. On average, daily revenues have risen by 205 rupees, while costs (including for mobile phones) have increased by 72 rupees. Thus, the profits of fishermen have jumped by 133 rupees a day—a 9 percent increase. The introduction of mobile phones has also had a modest benefit for customers, with the average price of sardines falling by 0.39 rupee per kilogram, or just under 4 percent.^a

Source: Jensen forthcoming.

a. This is consistent with findings in other countries. See, for example, a recent study from Lao People's Democratic Republic indicating that calls to and from suppliers are the most common reason for use of ICT services by small enterprises, many of which are household-based. See Song and Bedi (2006: 265).

farther away—usually have high monetary or nonmonetary costs. The value of electronic communication networks and the cost of alternatives usually mean that uptake of these services is rapid when they become available. In Kerala, when mobile phones became available, the telecommunications penetration rate among fishermen went from zero to an equilibrium rate of 60–75 percent in just a few months. This effect is also seen at the national level, where the uptake of telecommunications services grew 24 percent a year between 1995 and 2005.

Much of India's population could benefit from ICT-driven innovation. The effect on fishermen incomes described in box 6.1 could apply to any small enterprise involved in producing and distributing perishable goods such as fish, fruit, vegetables, and livestock products. Nearly three-quarters of India's population is rural.² In 2005, agriculture (including fishing, logging, and forestry) accounted for 19 percent of GDP and employed 60 percent of the workforce, making it the biggest sector of the Indian economy. Agriculture is dominated by small-scale firms and household enterprises. Thus, innovation brought about through ICT could positively affect a huge portion of India's population.

The availability of ICT infrastructure and services has increased dramatically in recent years. High investment in ICT infrastructure and services, increased competition, and lower equipment prices have raised teledensity and driven down prices. As a result, Indian consumers now enjoy some of the world's lowest charges for mobile telecommunications. By September 2006 there were 41 million wireline subscribers, 130 million wireless subscribers, and more than 1.8 million broadband subscribers (Telecommunications Regulatory Authority of India 2006). The number of wireless subscribers is continuing to grow rapidly, increasing by 55 percent in 2006, with an average of 6.5 million subscribers added in each of the last three months of the year, for a total of roughly 150 million wireless subscribers by end 2006—making India the world's fastest-growing market for mobile phones (*Economist* 2007). This rapid growth in penetration rates has reduced the price of information for individuals and businesses, making it easier to obtain information on, for example, prices of inputs and products. It has also allowed companies to introduce innovations in how they run their businesses, making it easier to stay in touch with staff, customers, and the various components of the supply chain.

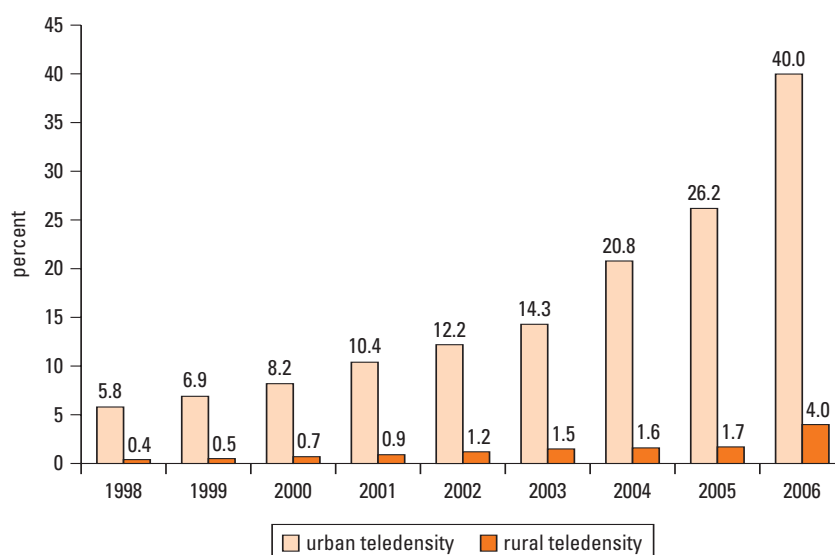
Still, despite the recent rapid increases in mobile and broadband subscribers, India continues to lag behind some countries, and there is a large and growing gap in teledensity between urban and rural areas (table 6.3). This gap is particularly stark in broadband access. For example, penetration in China, a country of comparable size, is 30 times that in India. Average penetration rates also hide major disparities in access between rural and urban areas. Teledensity in India is 40 percent in urban areas, but just 4 percent in rural areas (figure 6.1). Only 45 percent of India's population is covered by a mobile signal—compared with more than 90 percent in China and South Africa. Thus, a priority for India is to increase the availability of voice services in rural areas and ensure that broadband networks are developed as quickly as possible.

Table 6.3 Mobile and Broadband Penetration in Various Countries, 2005–06

Country	Mobile subscriber penetration, Q4 2006 (per 100 people)	Broadband penetration, 2005 (subscriptions per 100 people)
Brazil	54	1.0
Russian Fed.	111	1.0
India	13	0.1
China	33	3.0
Korea, Rep. of	84	28.0
Mexico	51	1.0

Sources: www.wirelessintelligence.com (mobile); PricewaterhouseCoopers 2006 (broadband).

Note: Mobile penetration rates of more than 100 percent can arise for a number of reasons—use of more than one handset per person or a single handset with multiple SIM cards, double counting as people switch networks, or the inclusion of dormant accounts. These figures should be considered a broad indication of users that allow comparison between countries.

Figure 6.1 Urban and Rural Teledensity (Fixed and Mobile) in India, 1998–2006

Source: Telecommunications Regulatory Authority of India.

Development of India's ICT networks will depend on the private sector. In India, as in most countries, competition has been the key driver of higher network rollout and lower prices for ICT services. The provision of telecommunications services has proven profitable for private companies, even in relatively poor and sparsely populated communities. Innovations in the manufacturing of communications equipment and in the design, operation, and retailing of mobile services have cut costs and made services more affordable—providing access to communications services to parts of the population that once had not been expected to be profitable. Policies to

ensure that networks reach deeper into rural areas should build on this success by encouraging competition and private investment in ICT. Looking ahead, there will be increased emphasis on the availability of broadband to businesses and households. Thus, policies should encourage the private sector to invest in innovative broadband infrastructure—particularly in areas not currently served, such as rural communities.

Recommendations for Improving Access to ICT

The recent improvements in India's communications infrastructure must continue. But the emphasis should increasingly be on providing rural ICT infrastructure and ensuring that high-speed data services are more widely available, particularly in underserved areas. A multifaceted approach to improving access to telecommunications services in both urban and rural areas is required. Key action areas include the following:

- *Reducing network costs to make marginal areas more commercially viable.* This could be done through measures such as reducing domestic roaming tariffs, promoting infrastructure sharing between operators, and facilitating access to land and building space at low cost and access to existing backhaul networks.
- *Expediting allocation of spectrum for wireless broadband rollout.* Freeing up more radio spectrum and making it available to operators of voice and data services would reduce rollout costs and enable operators to accelerate the provision of services, including broadband wireless services in rural areas. The government has de-licensed the 5.15–5.35 gigahertz (GHz) and 5.725–5.875 GHz bands for indoor use, and should de-license them for outdoor usage as well. De-licensing would allow users to deploy wireless networks at much lower cost and provide opportunities for innovation in wireless systems. Spectrum in other bands (such as 2.3, 2.5, and 3.5 GHz) should be reallocated for broadband wireless access. Spectrum in the 3.3–3.4 GHz band has been allocated to Internet service providers on a citywide basis. The government should consider allocating this spectrum in smaller geographic units to make more effective use of the resource.
- *Cutting taxes.* The government imposes various fees, levies, and taxes on telecom services. These include annual license fees of 6–12 percent, spectrum charges of 2–5 percent, and service taxes of 8–12 percent. For an industry growing so quickly, these taxes and fees should be reduced. In a high-volume business, lower taxes create a win-win situation for everyone. The government also imposes an 8 percent tax on Internet service providers. Reducing or waiving this tax would lower the cost of broadband access. In addition, some Indian states levy a 30 percent entertainment tax on broadband subscriptions. The central government should encourage state governments to waive this tax.
- *Revising policies.* The government should revise its policy definition of broadband, now defined as a minimum “always on” 256 kilobits per second (Kbps) connection. Comparator countries (Brazil, China, the Republic of Korea, the Russian Federation) have much higher definitions for broadband speeds.

- *Lowering network costs.* Network costs could be lowered by facilitating the rollout of backbone networks, encouraging competition in the provision of leased lines, and facilitating access to the networks of operators in dominant economic positions. Access to last-mile connectivity should also be facilitated, because its absence inhibits competition in backhaul and leased-line networks.
- *Providing targeted subsidies for rural mobile and broadband rollout.* This should be done in a way that rewards efficiency, maximizes private investment, and does not distort competition. Subsidies should be linked to the sharing of infrastructure and be for a limited period—say, five years—to avoid distorting competition.

Developing ICT Infrastructure for Universities and High-End Research Institutes

There is growing awareness that high-speed research and education networks accelerate the pace of new discoveries and the expansion of knowledge by enabling collaboration. Around the world, national research and education networks (NRENs) have become an essential part of R&D infrastructure (box 6.2). More than 70 countries connect researchers and scientists through high-speed networks with an emerging standard connectivity of 10 gigabits per second (Gbps), capable of transmitting data at 1 trillion bits a second—the equivalent of transmitting a two-hour DVD in

Box 6.2 What Are National Research and Education Networks?

National research and education networks (NRENs) were conceived to meet the needs of high-end users through a dedicated infrastructure that restricts data traffic to high-end purposes. Although the Internet is a sufficient data transfer vehicle for the average user, the target clientele of NRENs is high-end users—such as research scientists—who need to transmit and access images and large amounts of data for computationally intensive problems.

NRENs typically operate as a layered hierarchy of national backbone, state or provincial networks, and metropolitan area networks connecting individual campus networks. Institutions can either connect directly to a point of presence on the backbone or to a regional or metropolitan area network run by the NREN or a third party. Given the high capacity of the typical NREN backbone network, traffic congestion usually occurs at the local area network level. Thus, regardless of how much capacity the core has, the connectivity that researchers experience at each institute is limited by the connectivity of their local area networks.

NRENs integrate scientists into a wider research community and provide easier access to networked resources and equipment than would otherwise be available to users in different regions. Given the dedicated infrastructure and selective membership of NRENs, scientists are also assured better security for data transfer and can authenticate their collaborators.

Source: <http://internet2.edu>; www.geant2.net; Seth 2006.

four seconds.³ These networks generally connect almost all the universities in their countries and foster scientific and technological innovation. Their main impact on the innovation economy is through the potential for higher academic and research productivity using a high-speed mechanism to create and absorb knowledge by tapping into a global network. NRENs facilitate international collaboration through sharing of research data, joint experiments, conferences, building of databases, setting of standards, and sharing of equipment, and provide a motivating force for solving global problems such as climate change and infectious disease control (Wagner and others 2001: 102). The networks are also important for conducting frontier research in next generation networking technology that can lead to even higher-performance networks, and applications in health and education through the use of imaging and telepresence—such as distance medical diagnostics and operating procedures, and interactive distance education (box 6.3).

Although the United States and Western Europe are global leaders in high-speed research and education networking, many other regions are also investing in this

Box 6.3 Applications by National Research and Education Networks

High energy and nuclear physics (HENP). Worldwide, HENP scientists have been leading adopters of high-speed networking. Bandwidth use in the field is 1,000 times that of 10 years ago, enabling huge datasets to be shared and processed by collaborators studying heavy-ion collisions. The HENP network grew by 70 percent a year between 1992 and 1999, and since then by 100 percent a year. But the digital divide that prevents a number of HENP scientists in different regions from having access to high-performance networks has meant that these researchers cannot collaborate as equal partners in pushing out the HENP frontier.

Transmitting high-resolution images in real time. In October 2006, high-level specialists at the National AIDS Research Institute (NARI) in Pune participated in an interactive clinical education program on HIV/AIDS with counterparts at the Johns Hopkins University in Baltimore, Maryland (United States). The program was unusual in that neither group of scientists had left their home countries. Instead, clinical demonstrations were conveyed from Baltimore to Pune using a high-resolution, multipoint video conference in real time.

During one of the demonstrations Dr. Sanjay Kedhkar, a Johns Hopkins clinical instructor of ophthalmology, talked NARI scientists through his examination of an HIV-positive patient's retina while the scientists observed a three-dimensional image of the retina live onscreen. The image was transmitted through high-resolution video from Dr. Kedhkar's equipment to Johns Hopkins University's area network, which conveyed it to the European transnational network, GÉANT2, through the U.S. network, Internet2. GÉANT2 transmitted the data to India's network, Education and Research Network (ERNET), allowing NARI scientists to observe the image through the institute's connection to ERNET—all in real time. A year ago such an event would not have happened, simply because ERNET was not linked to GÉANT2.

Sources: Newman 2004; Johns Hopkins 2006.

Table 6.4 High-Speed Networks in Various Countries

Country	NREN	Core (domestic) network capacity (Mbps)	International connectivity (Mbps)
Brazil	RNP	Up to 10,000	1,000
Russian Fed.	RBNET	622	622 (multiple links)
India	ERNET GARUDA }	8–100	45
China	CERNET CERNET2 CSTNET }	2,500–40,000	4,500
Korea, Rep. of	KOREN KREORNET2 }	2,500–10,000	10,000
Mexico	CUDI	155	1,000

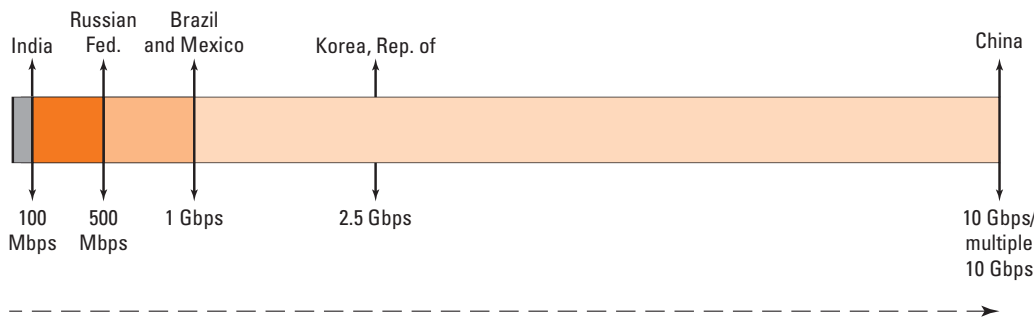
Source: Authors.

infrastructure. In the United States a nonprofit consortium, Internet2—created 10 years ago by academics at U.S. research universities—is the NREN entity that operates the high-speed national backbone network. This backbone uses a dedicated pair of optical fibers across the United States to provide a capacity of 10 10-Gbps wavelengths (100 Gbps)⁴ to Internet2 members, who include more than 200 U.S. universities, 70 corporations, 45 government agencies, 45 international organizations, and 35 state education networks. All members have a purpose related to research, education, or both.

Similarly, the U.K. Delivery of Advanced Network Technology to Europe (DANTE) is a nonprofit entity based in Cambridge, established in 1993 by a number of Europe's NRENs. DANTE runs GÉANT2, a transnational European high-speed network that provides high-bandwidth connectivity between European research and education institutes (see box 6.3).⁵ Similar networks operate in many other countries and regions, including East Asia and the Pacific and Latin America, with increasingly high-speed networks (table 6.4).

Yet India lags behind global comparators in high-speed networking for research and academic institutions. Two of the main factors that determine the effectiveness of an NREN for domestic and international collaboration are the capacity of the core network (measured as the rate at which data can be transferred through the core, in bits per second) and the bandwidth of links to international NRENs (figure 6.2). India's core capacity, provided by networks such as Education and Research Network (ERNET) and GARUDA (National Grid Computing Initiative), is 8–100 megabits per second (Mbps)—a fraction of the global standard connectivity of 10 Gbps.

Only in October 2006 did India establish a dedicated international link for research and education networking, when ERNET linked to GÉANT2 at a speed of 45 Mbps (with funding from the European Commission and Indian government).⁶

Figure 6.2 Capacity of International Links to National Research and Education Networks

Source: Authors.

Note: Emerging standard capacity of international links to NREN is in gigabits per second. Mbps = megabits per second.

Although this connectivity is a significant improvement from having no international link, it is still far more limited than its comparators—such as the multiple 10-Gbps links between GÉANT2 and Internet2, or the 2.5-Gbps link between GÉANT2 and Chinese research and education networks—restricting both the quality and amount of data that can be transferred to and from India.⁷ Moreover, most Indian scientists and researchers cannot effectively collaborate on scientific research or exchange ideas with their international counterparts because only a small portion of this community is connected to high-speed networks. South Asia in general compares poorly with the United States, Europe, East Asia and the Pacific, Latin America, and North Africa in core network capacity of NRENs and international connectivity.

No single entity in India is responsible for building an NREN, resulting in parallel high-speed networking efforts and duplicated resources. High-speed networking for research and education institutions in India is conducted by two organizations under the Department of Information Technology (DIT): ERNET and the Center for Development of Advanced Computing (C-DAC). ERNET was set up in 1986 using funding from the United Nations Development Programme and DIT (then called the Department of Electronics), with a mandate to create a research and education network for select universities and institutions of national importance. In April 2006 DIT also provided Rs 14.5 crore (approximately \$3.2 million) to fund C-DAC in launching a proof-of-concept initiative to connect 17 cities in India using a nationwide grid (*Times of India* 2006b). That grid, GARUDA—set up in partnership with ERNET—connects 45 research and education institutes through a virtual private network (a private communications network that can be used to connect over a publicly accessible network) with a backbone connectivity of 100 Mbps (*Times of India* 2006a). GARUDA is expected to supply about 60 percent of the supercomputing power available to the institutes and will be used for a range of data-intensive applications of national importance, including forecast models for disaster management.⁸ The Department of Biotechnology (DBT) is also involved in networking—through Biogrid, a virtual private network designed to connect DBT's bioinformatics centers

(Kolaskar 2006). Currently, the network connects 11 of the 62 bioinformatics centers through 2-Mbps dedicated leased circuit lines.

The Council of Scientific and Industrial Research (CSIR) recently proposed setting up a grid to connect its 38 labs using a backbone network of 155 Mbps, providing 2 Mbps connectivity to each (Seth 2006). However, with technology for high-performance networking progressing rapidly, most of these are examples of past technologies and capacities no longer being used by leading NRENs. In addition, the National Knowledge Commission, a high-level body created by the Indian government in 2005, has proposed building a National Knowledge Network that would connect 5,000 universities and research institutes all over India at a connectivity of 100 Mbps (National Knowledge Commission 2007). The lack of a single entity aggregating high-end user demand is possibly unattractive to international NRENs seeking to co-fund links to Indian networks.

The main responsibilities of entities that operate NRENs are to mobilize and aggregate demand for high-speed networking, manage underlying infrastructure through owned or leased models, and deliver services—including connections to high-speed global networks—at agreed standards. To ensure independence from the government in network operations, NRENs are typically designed as separate legal entities (usually nonprofit organizations) controlled by the research and education community, though they can be government funded. NREN funding arrangements vary by country. Internet2, for instance, receives no federal funding; it is supported entirely by corporate, university, and affiliate members.⁹ GÉANT2, however, is co-funded by the European Commission, with 93 million euros (or roughly \$120 million) for a four-year period that started in September 2004. Partnering NRENs connected to the network provide the remaining funding through subscription fees. For more information, see box 6.4 and table 6.5.

Box 6.4 Trends among National Research and Education Networks in Europe

- The most common capacity among NRENs in 28 European Union/European Free Trade Agreement (EU/EFTA) countries is 10 Gbps.
- In 2006, only three EU/EFTA NRENs did not have a capacity of at least 1 Gbps.
- Primary and secondary schools are increasingly being connected by NRENs in many countries, with connections mainly funded by ministries of education.
- More NRENs are switching to dark fiber—unlit fiber put in place for future use—which gives them more control over network infrastructure and makes upgrading capacity easier.
- Developments in fiber optic technology are increasingly allowing NRENs to leapfrog to higher-capacity networks. (See table 6.5.)

Source: TERENA Compendium of National Research and Education Networks in Europe (www.terena.nl/compendium/).

Table 6.5 Core Network Capacity in Selected EU/EFTA National Research and Education Networks
(megabits per second)

Country	NREN	2001	2002	2003	2004	2005	2006
Belgium	BELNET	622	1,000	4,976	4,976	4,976	10,000
Czech Republic	CESNET	2,488	2,488	2,500	2,488	2,488	10,000
Finland	FUNET	2,488	2,488	2,488	2,488	2,488	2,488
France	RENATER	2,488	2,488	2,488	2,488	2,488	2,488
Germany	DFN	622	2,488	10,000	10,000	10,000	10,000
Hungary	NIIF/HUNGARNET	155	2,488	2,488	2,488	10,000	10,000
Italy	GARR	—	2,488	2,488	2,488	2,488	10,000
Netherlands	SURFnet	2,488	10,000	10,000	10,000	10,000	10,000
Norway	UNINETT	2,488	2,488	2,488	2,488	2,488	2,488
Poland	PIONIER	155	155	622	10,000	10,000	10,000
Spain	RedIRIS	155	155	2,488	2,488	2,488	2,488
Sweden	SUNET	622	10,000	10,000	10,000	10,000	10,000
United Kingdom	UKERNA	2,488	2,488	10,000	10,000	10,000	10,000

Source: TERENA Compendium of National Research and Education Networks in Europe, 2006 edition (www.terena.nl/compendium/).

Note: EU/EFTA = European Union/European Free Trade Agreement countries; = not available. Although the TERENA survey compiles information from 47 NRENs in 46 countries, the table provides information only on select EU/EFTA NRENs.

Recommendations for Improving ICT Infrastructure for Universities and High-End Research Institutes

India should upgrade its high-speed networking capacity for research and education institutions—with achieving clarity on the entity to manage the network an urgent priority. Although Indian policy makers recognize the importance of advanced networks in the knowledge economy, they are constrained by two issues: the cost of NREN infrastructure and the appropriate organizational structure to deploy and manage the networks. Discussions on the precise configuring of a top-level NREN are beyond the scope of this report. Thus, the three recommendations below point to broad steps that India needs to take in setting a strategy for nationwide high-speed networking.

1. *Establish a clear NREN entity.* A new entity could be established to circumvent the problem of multiple existing initiatives, each with its own interests. Alternatively, an existing organizational initiative could be reconfigured and its mandate broadened. Whatever approach is taken, what is essential is clarity on the NREN entity's structure. A panel of willing partners of major NRENs could be convened to help the entity strategize on scale, implementation methods, network operations, and global partnerships. The entity has to be a forward-looking, technically oriented organization that will allow India to leapfrog into state-of-the-art technology and skip the network development phases that other NRENs

have undergone. The entity must also oversee the engineering and operation of NRENs, as well as drive the community that participates in developing it.¹⁰

2. *Foster programmatic rollout.* Any NREN entity would need to take into account international best practices when setting up a prototype high-speed network model before phasing into a larger-scale network—aggregating unused infrastructure and building on it as needed. The prototype phase would be used to test the selected management model, partnership arrangements, and forecasted demand, and to incorporate lessons from other national and international infrastructure management models. The NREN entity would also need to decide whether to use an own or lease model for wider outreach and the type of telecom carriers (public or private, and by region) that would be the best partners. Finally, the entity should provide connectivity for end-user research and education institutions in phases—for instance, first to high-demand areas and clusters with a concentration of universities and research institutes, then to institutes of national importance and secondary and primary schools.
3. *Encourage demand.* The high capital investment required to establish a top-level NREN implies higher risks if the infrastructure is underused. The business model used to operate the NREN (including aspects such as the business arrangement with partnering telecom carriers and internal fee structure) can have enormous implications for its success. Making the NREN affordable in the early stage can be an effective way of demonstrating the many uses of high bandwidth (*Hindu* 2006). Ensuring that NRENs are used also means subsidizing academic institutions in their cyber infrastructure investments at the campus and local levels. Given the high capacity of the typical NREN backbone network, traffic congestion usually occurs at the local area network level. Thus, regardless of how much capacity the core has, the connectivity that researchers experience at each institute is limited by the connectivity of their local area networks, which can be a barrier to adoption. Government grants could circumvent this dilemma and increase the use of NRENs. The National Science Foundation, for instance, provided critical funding to U.S. universities in the three to four years following Internet2's inception to subsidize their connections to the national backbone network. In addition, if the culture and incentive regimes in academic and research institutions do not demand the quality of research that requires the use of an NREN, nationwide connectivity of these institutes could result in the infrastructure being underused. Thus, the success of a top-level NREN partly depends on institutional conditions that create demand for its use.

Notes

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1. WTO data cited in Fernandez and Gupta (2006).
2. India census, 2001.

3. <http://internet2.edu>
4. Internet2 recently started to migrate its traffic to a new backbone that offers connectivity 10 times that of the previous one, Abilene, which had a capacity of 10 Gbps. The first 10 10-Gbps links connected Washington, DC, New York, and Chicago in late 2006. Full migration is expected to be complete in summer 2007.
5. More information is available at <http://www.geant.net/>.
6. At the time of writing, Internet2 was negotiating a 45-Mbps link with ERNET that would provide a dedicated connection from Chennai to Singapore. This link would be cofunded by the U.S. National Science Foundation.
7. Johns Hopkins University 2006; informal communications with Heather Boyles, Director, Member and Partner Relations, Internet2 (January 2007) and Michael Foley, Consultant, South Asia Region, World Bank (January 2007).
8. *Hindustan Times* 2006. (See also www.hindustantimes.com and http://www.garudaindia.in/press_release.htm.)
9. Internet2 universities have made more than \$80 million a year in investments on their own campuses and corporate members have committed more than \$30 million over the life of the project.
10. Personal communication with Prof. Harvey Newman, California Institute of Technology, January 13, 2007.

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Enhancing Innovation Finance

Inderbir Singh Dhingra

Accessing finance for innovation is a challenge, even in economies with well-developed financial markets. Although access to finance does not pose as big a challenge for large and even medium firms, it is a severe constraint for smaller enterprises, start-ups, and innovative grassroots projects. Access to finance for innovation is an important link in the innovation cycle—covering innovation costs, supporting incubation, and financing commercialization—making innovation sustainable and rewarding. Around the world, constraints in financing innovative enterprises include the following:

- Actual and perceived risks arising from the higher failure rates of innovative micro, small, and medium enterprises (MSMEs), and unproven products and business models
- Lack of management and operational capabilities among technopreneurs and scarce mentoring resources
- Information asymmetries—given that entrepreneurs and innovators are more comfortable with innovation than are financiers, partly because of lack of technical expertise among financiers
- High transaction costs of dealing with start-ups and MSMEs given the small size of seed and early-stage investment relative to investment efforts (due diligence) and the time required in hand-holding and mentoring start-up management teams.
- Difficulties in attracting experienced investment professionals as fund managers in seed and early-stage funds as a result of the long gestation period for returns on such investment and the lower remuneration—the 2.0–2.5 percent management fee from managing small funds (\$10 million–\$30 million) is less than that from managing larger, later-stage, and private equity funds.

- Lack of reliable, adequate track records and financial information (adverse selection challenge).
- Lack of adequate collateral and the intangible nature of the assets of the enterprises.
- Institutional and legal factors, including competition-related distortions and inefficiencies in the banking sector, an underdeveloped legal system and enforcement, and inadequate information infrastructure.¹

These constraints are also present in India, which has a well-developed public and private equity market relative to most other emerging markets.²

Government funding has played an important role in India's early-stage technology development (ESTD), but has not achieved the desired scale and quality of research and development (R&D) investment and commercialization. As discussed in earlier chapters, there is considerable scope for strengthening India's performance in knowledge creation and commercialization, raising R&D, increasing the effectiveness of public R&D, and deepening interactions among R&D labs, universities, and the private sector by, among other things, restructuring or scaling up grant-based initiatives. Furthermore, new initiatives are needed to stimulate knowledge creation (see chapter 2).

Although venture capital and private equity have been expanding in India in recent years, funding of seed and early-stage finance remains a key challenge. In 2005, early-stage funding accounted for just 13 percent of the deals by the venture capital and private equity industry. In dollar terms, early-stage deals account for 4–6 percent of investment by the venture capital and private equity industry.³ Despite a significant number of major funds being created in India in the past 12–18 months, there remains a bias toward larger funds, information technology (IT), and proven business models. New efforts in seed and angel funding that are trying to fill the gap still have insufficient capital to meet the needs of early-stage finance.

The supply of early-stage venture capital could be increased by creating incentives for domestic liquidity from wealthy individuals and allowing insurance and pension funds to provide early-stage venture capital. In addition, a fund of funds could be created to spur public-private venture capital funds, with the goal of attracting private capital and international and domestic expertise and fund management experience in early-stage venture capital. Finally, to address the demand side for the venture capital industry, the flow of deals must be enhanced through multipronged reforms to improve the overall innovation climate as well as the governance, incentives, and design of India's innovation system, as discussed in previous chapters. This involves restructuring and enhancing public support for ESTD and incentives for R&D commercialization in labs and universities—promoting a culture of entrepreneurship and social support, providing complementary infrastructure and an enabling environment for innovation and entrepreneurship, and improving the overall investment climate for firms.

The magnitude of the financing gap for technology absorption by MSMEs is unknown, but the constraints facing MSMEs in financing new investments suggest

its significance. Credit to Indian micro and small enterprises (MSEs), which includes financing for upgrading technology, fell as a share of net bank credit between 2003 and 2006. Government schemes to spur technology financing for MSEs, such as the Credit Linked Capital Subsidy Scheme for upgrading technology in small-scale industries, have also not allocated enough capital to support knowledge absorption by firms. Enterprise surveys suggest that funding for absorption of innovative practices is more constrained for smaller enterprises and traditional industries. Measures to improve access to finance for MSMEs would improve access to finance for innovative MSMEs wishing to upgrade technology. Possible government actions include providing matching grants for technology absorption as well as addressing constraints to MSME finance—including improving credit information on MSMEs, strengthening collateral and mortgage registries, reforming the bankruptcy framework, and facilitating leasing.

Financial Support for Early-Stage Technology Development

The higher risks associated with seed capital for ESTD result in fewer sources of private funding. The literature cites two key reasons the market for funding ESTD,⁴ and even early-stage business operations, may not be efficient—making the case for public intervention.⁵ The first is the partial appropriability of returns from investment in R&D—due to positive spillovers—which does not allow original inventors or investors to capture all the benefits of their inventions and innovations. This results in lower spending on ESTD than would be socially optimal. The second reason is information asymmetry, arising from the gap between the information available to inventors and investors. Most investors are poorly equipped to quantify the risks and technical and market uncertainties associated with most inventions. Moreover, the due diligence required to close this information gap discourages investors (angel investors, venture capitalists), who prefer to wait to see the business case for a new technology at least partly demonstrated before investing.

The role of government and angel investors is more important in ESTD. Informal sources and grant-based government programs play a larger role in ESTD funding, injecting capital into a company's product concept stage—when the idea is being conceptualized. ESTD funding can continue to the seed stages of a company's development. In the United States, for example, federal and state governments provide 23–30 percent of ESTD finance, while angel investors contribute 24–27 percent. Venture capital contributes only 3–8 percent.⁶ In India, government programs have played a larger role in funding early-stage finance than have angel investors and university-funded incubators. Formal groups of angel investors, such as the Band of Angels, have been created only recently. University-funded incubators have played an important role in giving initial support, but venture capital is not always available through these incubators. Moreover, many of these incubators are not adequately funded and lack facilities to support a large number of entrepreneurs. Government support for ESTD has mainly been in the form of grants, soft loans, and government-funded incubators.

The main government programs have varied in their goals—from promoting high-technology ventures, as with the New Millennium Indian Technology Leadership Initiative (NMITLI) (though not funding start-ups), to funding indigenous technology, as with the Technology Development Board (TDB). Although these programs have targeted early-stage funding, some seem not to have been managed well, and the funds have not been used (see chapter 2).

Although data are lacking on the demand for early-stage financing in India, the vibrant innovation environment signals high potential for entrepreneurial activity (Dossani and Desai 2006). A growing number of graduates, the boom in IT and IT-related sectors, and the rise in business-savvy young professionals with the potential to create spin-off ventures create a rich entrepreneurial environment in India. The risk in ignoring the financing needs of these potential entrepreneurs at the conceptualization and proof-of-concept stage is that the economy loses by allowing only a small portion of its entrepreneurs to achieve their potential. As discussed in chapter 2 and shown in figure 7.1, a number of government programs target ESTD finance.

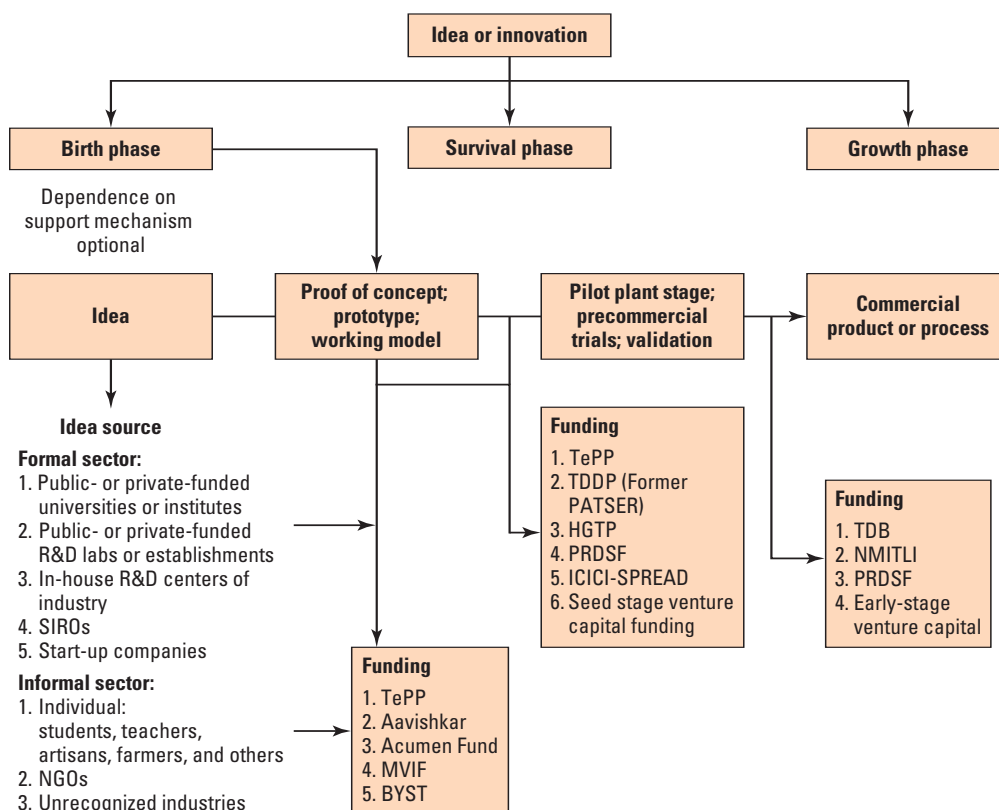
ESTD efforts are not creating a sufficient level and quality of demand for the venture capital industry. As discussed in earlier chapters, anecdotal evidence and indicators of India's performance in knowledge creation and commercialization through R&D are poor. Low overall R&D, dominance of public R&D, limited interaction between R&D labs, universities, and productive sectors of the economy—all point to a need to restructure and scale up grant-based initiatives.

Recommendations for Improving ESTD Financing

The various ESTD financing schemes were discussed in chapter 2, and three recommendations based on that analysis are summarized here.

1. *An independent evaluation of government programs is needed.* The first step in correcting the mismatch between the need to promote entrepreneurial ventures and the shortage of capital in ESTD is to assess government spending on ESTD programs, with a view to improving governance, correcting design flaws, and addressing funding gaps:
 - The evaluation should review the roles, goals, governance structures, costs, performance, outcomes, and impacts of such programs.
 - The programs, including government-supported business incubators, should be assessed to gain a broad understanding of which sectors of ESTD the government currently finances and the impacts and returns of this financing.
 - Based on these reviews, changes should be made in the programs—including their expansion, consolidation, and closing, as appropriate.
2. *Efforts should be made to create new initiatives and build on existing programs.* As recommended in chapter 2, efforts should be made to develop initiatives that

Figure 7.1 Mapping of Early-Stage Finance in India



Source: World Bank; adapted from UN ESCAP (2005).

Note: BYST = Bharatiya Yuva Shakti Trust; HGTP = Home Grown Technology Program; ICICI = ICICI Bank; MVIF = Micro Venture Innovation Fund; NGOs = nongovernmental organizations; NMITLI = New Millennium Indian Technology Leadership Initiative; PATSER = Programme Aimed at Technological Self-Reliance; PRDSF = Pharmaceutical Research and Development Support Fund; SIROs = scientific and industrial research organizations; TDDP = Technology Development and Demonstration Program; and TePP = Techno-entrepreneurs Promotion Program.

stimulate knowledge creation, building on successful programs and expanding and consolidating where appropriate. As discussed earlier in this book, many government support programs have overlapping roles and goals. Program resources are fragmented, and most programs are operated by government bodies with little private sector participation in their management and operations.

3. Particular attention needs to be paid to improving and scaling up existing ESTD funding mechanisms for grassroots innovation projects based on the evaluation. These mechanisms include efforts by the Council of Scientific and Industrial Research (CSIR) to demonstrate and pilot grassroots technology and provide R&D and grant funding to support prototype development and piloting for grassroots innovators through the Grassroots Innovation Augmentation Network (GIAN) and National Innovation Fund (as discussed in chapter 4).

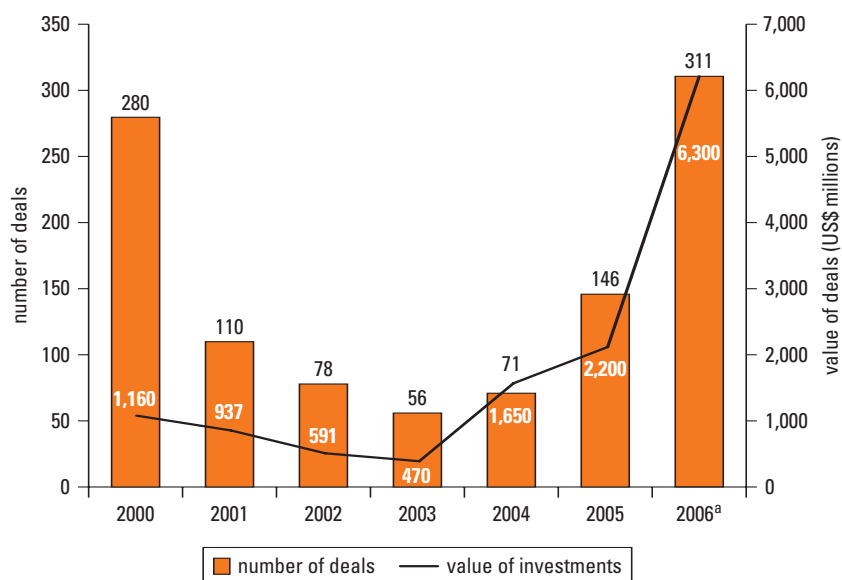
Early-Stage Venture Capital

Venture capital plays a crucial role from an economic standpoint and is important to commercialization of R&D. Start-ups and MSMEs funded by venture capital tend to be the more innovative firms in an economy, contributing to economic productivity. Venture capital and angel investor financing is accompanied by management support, advice, reputation, and other forms of mentoring critical to business success. Despite contributing less early-stage funding than other sources—such as government and angel investors—in the United States (as well as Israel and Taiwan, China), venture capital has been associated with higher patenting, a larger share in industrial innovation relative to its share in R&D, and an overall increase in innovation (Kortum and Lerner 2000; Avnimelech and Teubal 2005a; Saxenian 2001, 2005). Around the world, venture capital has also been recognized for advancing the information and communication technology (ICT) revolution, enabling countries to catch up with international peers, deepening R&D, and facilitating the transition to knowledge and learning economies (Avnimelech and Teubal 2005b).

The challenge is in attracting venture capital at the seed and early stages of business. Venture capitalists want to maximize financial returns for their investors. They do not fund R&D, and prefer to support firms that have moved beyond the product development stage and to proven technologies and business models (Auerswald and Branscomb 2003). Still, venture capital firms are crucial for supporting early-stage financing—and with the right incentives and efforts to cut the costs of information asymmetries, can play an important role in seed and early-stage finance for innovative firms.

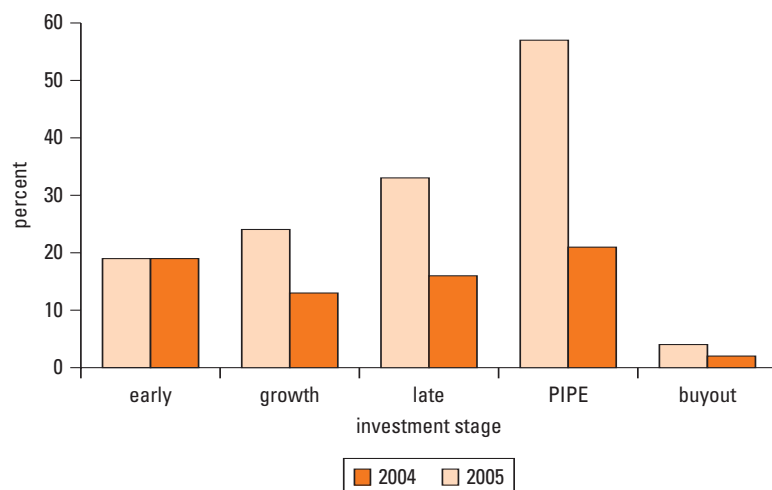
Venture capital and private equity activities have expanded in India in recent years. There has been great interest in investing in India in the past few years, from both domestic and international venture capitalists. The number of venture capital (including early-stage) and private equity funds being created by seasoned domestic fund managers has expanded significantly in the past 12–18 months. The interest of international (especially Silicon Valley) venture capitalists has also increased, with many creating India-dedicated funds and allocating more resources to exploring deals in India. In 2005, venture capital and private equity investment was \$2.2 billion—almost twice the amount in 2004 (figure 7.2). Furthermore, the number of deals and rounds of financing rose from 71 in 2004 to 146 in 2005, and is expected to more than double again in 2006.

Still, funding of seed and early-stage deals remains a key challenge. Despite the increase in funding from the venture capital and private equity industries, in 2005 early-stage funding deals accounted for just 13 percent of all deals by these industries and 4–6 percent of their investments (figure 7.3). Still, the average size of deals has grown in India—from \$8 million in 2002 to \$15 million in 2005. However, early-stage funding (especially seed and series A and B capital⁷) has not recovered from the burst of the market bubble in 2000, having suffered the most in 2000–03 and remaining negligible in 2004–05, despite a significant increase in investments and

Figure 7.2 Venture Capital and Private Equity Deals in India, 2000–06

Source: Evalueserve Inc., India Venture Capital Association, and Venture Intelligence India.

a. Estimates by Evalueserve.

Figure 7.3 Distribution of Venture Capital and Private Equity Deals by Investment Stage in India, 2004–05

Sources: Venture Intelligence; TSJ Media.

Note: Early-stage deals are first and second rounds of institutional funding for companies less than 5 years old and not part of a larger business group. Growth-stage deals are third and fourth rounds of funding or first and second rounds of institutional investments for companies more than 5 years old or floated by large business groups and less than 10 years old. Late-stage deals are for companies more than 10 years old or pre-IPO (initial public offering) deals. PIPE (private investment in public equity) deals are investments in listed companies through a preferential allotment or private placement of shares, warrant, or both.

Table 7.1 Number of Early-Stage Deals in India, 2000–05

Type	2000	2001	2002	2003	2004	2005
Seed	74	14	7	5	6	5
Series A and B	68	22	9	8	23	14

Source: Venture Intelligence, TSJ Media, and Evalueserve Inc.

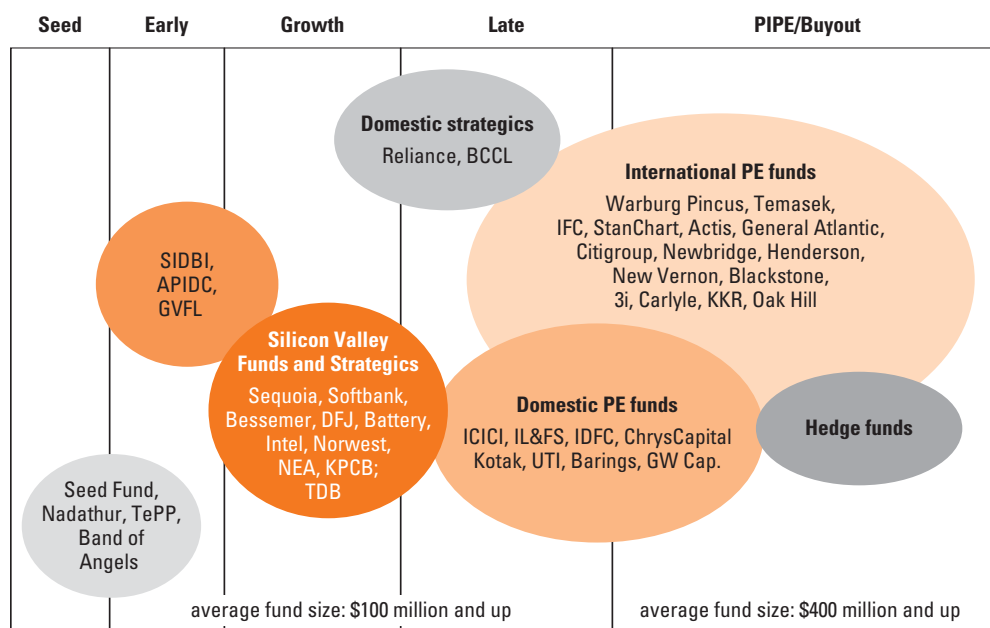
deals in other venture capital and private equity categories (table 7.1). Most growth has been in the mid-market segment of the venture capital industry (under \$10 million). The challenge is greatest for start-ups requiring investments of less than \$2 million–\$3 million, especially investments in the seed-stage range of \$0.5 million–\$1.0 million.⁸

Venture capital biases have resulted in disproportionate funding for certain early-stage ventures. The bias toward later-stage ventures often results in “overfunding” of start-ups by venture capital firms reluctant to do smaller transactions—an approach that is not always in the interests of efficiency and discipline of the start-ups. Another key feature of the venture capital–private equity scenario is the bias toward funding IT and IT-enabled service companies, which received 61 percent of the funding from the venture capital–private equity industry in 2005 (though there was more sectoral diversification in 2006). Most of these resources and efforts are directed toward early-to-growth-stage start-ups and those with cross-border business models (either addressing the international—especially U.S.—market or U.S. firms planning to off-shore operations or R&D in India).

Despite the significant number of major “India dedicated” funds raised in the past 12–18 months, there remains a bias toward larger funds, IT, and proven business models. Silicon Valley venture capitalists interested in India are inclined to take minimum exposures in the \$10 million–\$15 million range to justify the transaction costs associated with doing deals. Some, such as Bessemer Ventures, have drastically shifted their business models for India, taking equity exposures in large private equity transactions in non-IT firms instead of the Silicon Valley model of being early-stage technology investors. Even “early-stage” funds such as Helion Venture Partners prefer cross-border business models. The government-supported venture capitalists created in the early 1990s—the Small Industries Development Bank of India (SIDBI), Gujarat Venture Finance Ltd. (GVFL), and Andhra Pradesh Industrial Development Corporation (APIDC)⁹—along with Westbridge-Sequoia, remain the only major players for \$0.5 million–\$3.0 million investments (figure 7.4).

New efforts in seed and angel funding (Seed Fund, Band of Angels, Nadathur Holdings) trying to fill the gap have insufficient capital. Funds are also being provided (mostly in the form of grants) to some leading technology incubators by the Department of Science and Technology (see chapter 2). Estimates by the Seed Fund indicate that existing money for seed financing in India, including from government-sponsored funds and private sector efforts, is much less than is required.¹⁰ Total cumulative start-up capital available in this segment is \$25 million–\$35 million—enough to help 75–100 start-ups get off the ground. But available series A and B

Figure 7.4 India's Venture Capital and Private Equity Landscape: Skewed toward Larger and Later-Investment-Stage Deals



Sources: Venture Intelligence; World Bank.

Note: Those companies not listed here are known exclusively by their acronyms. APIDC = Andhra Pradesh Industrial Development Corporation; BCCL = Bennett Coleman & Co.; DFJ = Draper Fisher Jurvetson; GVFL = Gujarat Venture Finance Ltd; IFC = International Finance Corporation; IL&FS = Infrastructure Leasing & Financial Services; KKR = Kohlbert Kravis Roberts & Co.; KPCB = Kleiner, Perkins, Caulfield, and Byers; NEA = New Enterprise Associates; PIPE = private investment in public equity; SIDBI = Small Industries Development Bank of India; TDB = Technology Development Board; TePP = Techno-entrepreneurs Promotion Program; UTI = UTI Ventures.

capital exceeds \$1 billion, which could be absorbed by 150–200 companies. For the series A and B capital to be used well (assuming, optimistically, that one in three early-stage funded start-ups graduates to the next stage), there need to be 450–600 start-ups that the early-stage funding community finances today—and that does not account for future growth. Hence, from a purely supply-side perspective, the total funding available at the early stage—especially in the range below \$2 million—is a bottleneck. Another possible manifestation of this issue is that R&D commercialization is very low, as are spin-offs from public and private R&D labs and universities. This represents a challenge as well as an opportunity.

The growth of early-stage financing for start-ups and innovative MSMEs is constrained by both supply and demand factors, pointing to the need for a realignment of expectations and business models in the venture capital industry targeting India. On the one hand, entrepreneurs complain about the lack of early-stage financing. On the other hand, venture capital–private equity activity had been expected to almost triple in 2006 relative to 2005.¹¹ In addition, the number of Silicon Valley funds coming to India and those being created specifically for India has shot up in the past

12–18 months. Venture capital fund managers complain about the lack of deal flows and idea generation. This is arguably the result of different expectations on both sides.

Most Silicon Valley and other new venture capital funds planning to invest in India are based on expectations of a pool of a U.S- or Israeli-type start-up base—with international business models, product companies, and the like. Furthermore, they seem to want to invest in sectors that they are more comfortable with—IT, telecommunications, and Internet products and services. Much of the entrepreneur base coming out of India may be predicated on a domestic market, consumer-based model, from first-time entrepreneurs with experience in service businesses and not necessarily the intellectual property-led product model that Silicon Valley venture capitalists are used to. Moreover, the levels of evolution and sophistication of these entrepreneurs are unlikely to meet the expectations of Silicon Valley venture capitalists (Evalueserve 2006). Finally, as noted, the deal-size filter of the new entrants still would not address the seed and series A and B needs of Indian entrepreneurs. A realignment of expectations and business models in India's venture capital industry is highly likely in the coming years.

On the supply side, a more rapid scaling up of early-stage financing would be facilitated by addressing the following issues:

- *Lack of adequate, relevant expertise among venture capitalists* and perceived unattractiveness of the effort required relative to the returns in investing in early-stage companies—which explains the inclination of India's venture capital-private equity industry to invest in later-stage companies needing growth capital or early-stage businesses adopting variants of demonstrated business models. In addition, the domestic and foreign financial sector and nonresident Indian dominance of venture capital have led to a venture capital-private equity industry that shies away from riskier, more innovative, and business-building venture capital and favors less labor-intensive, less risky, and more finance- and business-restructuring, later-stage investment. The larger share of private equity transactions is a manifestation, at least in part, of this phenomenon.
- *Difficulty in attracting experienced professionals in seed and early-stage fund management.* Three problems exist here: first, the significant effort and cost involved in continual hand-holding and mentoring management of a start-up; second, the long gestation period for returns in seed and early-stage investment relative to late-stage and private equity investment; and third, the lower remuneration arising from the fact that the 2.0–2.5 percent management fee from managing small funds (\$10 million–\$30 million) is less than that from managing larger, later-stage, and private equity funds.
- *Inability to channel domestic market liquidity into early-stage funding.* The negligible funding from wealthy individuals and the virtual absence of funding from pension and insurance funds have deprived the industry of stable, long-term sources of capital available in more developed markets. Restrictive investment guidelines constrain the ability of pension and insurance funds to

invest in venture capital. Venture capital funding was once classified as mandated lending for banks, but no longer. Moreover, the Reserve Bank of India has increased the risk weighting for venture capital funding for banks. The tax treatment and absence of incentives for venture capital relative to other asset classes—especially public equity, debt, and real estate—has made venture capital unattractive to rich people.

- *Inadequate legal, regulatory, and tax environment* (see Dossani and Desai 2006). India's policy and regulatory environment for venture capital can generally be considered pro-investor and has been improving, moving toward international best practice. Although the legal, regulatory, and tax environment has not been a binding constraint in attracting large and medium funds, bureaucratic hurdles need to be eased for domestic and foreign venture capitalists looking to operate in India—particularly for smaller, niche funds. For example, rules need to be clearer about the taxation of ventures, investors, and funds, as do the implications for the legal and institutional structures of venture capital firms. In addition, there are multiple regulations and little harmonization of guidelines across government agencies (Securities and Exchange Board of India, Reserve Bank of India, Central Board of Direct Taxes, Ministry of Company Affairs). There are also sectoral and security restrictions on investments by venture capitalists. Finally, investor rights are unclear as well.

On the demand side, the early-stage venture capital environment would be more attractive if the following issues were addressed:

- *A limited number of deals are bankable.* India has been relatively unsuccessful in nurturing a culture of entrepreneurship—especially of start-ups spinning off from R&D labs, education institutions, and large corporations. In 2003, the number of registered firms in India grew by 4.4 percent, compared with 8.6 percent in China, 9.7 percent in Ireland, 19.4 percent in the United Kingdom, and 23.4 percent in Germany (Klapper and others 2006). This may be due to a variety of factors, such as the incentives for public R&D and education institutions (as discussed in previous chapters), the lack of a social safety net, sociocultural attitudes toward failure, and the legal framework for business entry, operations, and exit.¹² In addition, the gap in precommercial financing and ESTD—typically supported by public institutions to spur R&D investment—results in too few spin-offs; in India such funding could come from the venture capital industry. Moreover, financiers often complain about the limited number of “big” ideas with the potential to provide returns as high as 200–500 percent, to satisfy portfolio diversification criteria.
- *Although Indian entrepreneurs typically possess technical and domain expertise on par with their Western counterparts, they lack skills in marketing, sales, business development, and financial planning and processes.* With such skills, the expected effects of venture capital in nurturing early-stage business would be much higher. The lack of such skills discourages venture capitalists from investing in very

early-stage businesses headed by inexperienced entrepreneurs with new business models, but also presents a chicken-and-egg situation—whereby the venture capital industry itself lacks sufficient personnel with operating experience that could nurture “raw” investments.

- *The risk perception associated with start-ups and MSMEs is higher in India due to investment climate bottlenecks.* Surveys by the World Bank and others point to the difficulties facing Indian firms relative to those in developed and other emerging markets. These difficulties stem from three issues. The first is the lack of adequate, reliable infrastructure. The second is the burden of business regulations, which result in significant management time being spent dealing with government regulations. And the third is the cumbersome legal system, which makes contract enforcement and business exit tedious, expensive, and time-consuming.¹³ In addition, corporate governance and financial transparency standards are lower in Indian firms than in more developed markets, further increasing the risk perception of deals.

Recommendations for Improving Early-Stage Venture Capital Financing

Governments can increase the supply of venture capital by investing public funds in these companies or by making it more attractive for nongovernment sources to do so. Investors seek to generate the highest risk-adjusted returns on their capital. In many countries they believe that the potential returns from venture investments do not justify the risks. Thus, government support programs that seek to encourage private investment must either enhance potential returns or increase the supply of funds to early-stage projects. Specific interventions include direct participation, or “seeding” of venture funds; tax credits, as a direct offset of a share of investors’ capital investment; government loans or loan guarantees to licensed venture funds; leveraged equity participation by government in private equity funds to increase the potential returns to private investors; and partial guarantees against losses for investors in venture funds—only up to certain levels, to ensure that investors take sufficient risks themselves.

First, the supply of early-stage venture capital can be increased by extending incentives for providing domestic liquidity to the industry. Changes in tax, Securities and Exchange Board of India, and insurance and pension fund guidelines could attract domestic investment in early-stage venture capital by doing the following:

- *Making it more attractive for wealthy individuals to invest in venture capital funds.* Fiscal incentives could encourage wealthy individuals—including those with domain knowledge and an appetite for risk—to plug the gap in angel investment. Investments in eligible funds and ventures could be given tax credits. In addition, the Securities and Exchange Board of India could permit “accredited” wealthy individuals’ investments in eligible venture capital funds to enjoy the same tax benefits (tax pass-through) available to registered funds under current regulations. This could provide a useful way to connect domestic and foreign angel investors to Indian start-ups, especially because the costly and complex

Box 7.1 International Experience with Funds of Funds to Spur Public-Private Venture Capital Funds

The more successful government support programs for venture capital funds have been those structured as public-private partnerships where the government is a financial backer—not a manager—of the fund. Responsibility for investment decision making rests with the private partner. The government provides capital (often providing leveraged returns to the private partner) and maintains oversight. Around the world, such public-private models have essentially been variants of the U.S. Small Business Investment Company (SBIC), created in 1959 to attract fund managers (from industry or with previous venture capital experience) who could bring domain expertise to the venture capital industry. The private manager (partner) raises capital commitments independently, supported by the government through equity contributions to the venture capital fund twice the private partner's contribution. The government also provides soft loans, enhancing private returns.

Israel's highly successful Yozma program aimed primarily to attract foreign domain expertise. The government contributed 40 percent of the financing for a foreign venture capital fund, with the rest coming from the fund. The returns to the foreign fund were enhanced by giving the option of buying out the government stake at a predetermined rate within five years. Other models, like Australia's Innovation Investment Fund and the U.K. Enterprise Capital Fund, have followed similar principles.

Source: Author.

procedures for establishing a venture capital fund in India deter individuals. Eligible funds and start-ups would be strictly defined to ensure support only to funds that invest in truly early-stage ventures (as defined by the size of the fund and maximum investment size, and restricted to the first or second rounds of external funding received by the firms).

- *Relaxing investment guidelines for pension and insurance funds* to allow them to increase their investments in venture capital funds, within prudential norms. Again, eligible funds could be defined to ensure that financing is directed toward early-stage businesses.¹⁴

Second, a fund of funds should be created to spur public-private venture capital funds targeted at early-stage investing. Learning from similar interventions elsewhere (box 7.1) and factoring in India's governance and administrative realities, a fund of funds could be created to attract private capital and professionals—with foreign or domestic domain knowledge and management experience—in a series of (“drop-down”) public-private venture capital funds by increasing potential returns or reducing potential risks. The investment restrictions of the program could support the government's development goals (say, by investing only in specified, eligible start-ups). The ultimate objective of the government support program would be for a

successful drop-down fund to subsequently raise funds based on its record, without government support, to be free of regulation. By supporting the first fund, therefore, the government would facilitate much more private capital for venture investments in the future. Considerations in designing the fund of funds include the following:

- *The government provides leveraged returns to private investors in drop-down funds.* To form the base of venture investment funds, private fund managers (experienced individuals, institutions, or both) would secure investment commitments from unrelated private sources. The government would provide a certain amount and limit its share of the profits to a certain interest rate plus a certain share of cash distributions from the funds. The remaining profits would be paid to the private investors and fund managers, increasing (or leveraging) their returns. These enhanced returns would make venture capital funds attractive investments for private investors and individuals with domain expertise and mentoring skills.
- *Government support (or a separate window of government support) could be used to reduce risk for risk-averse investors such as Indian institutions.* In this case, private investors would put up all the money for venture capital funds by purchasing units that are, as an illustration, one-third equity and two-thirds 10-year debt. The government would guarantee repayment of any debt not repaid from cash distributions from the fund. Because accrued interest will normally be greater than investors' equity investment, investors would know that, at the very worst, they will recover the full cost of their investment. At best, investors will realize the high returns that the funds expect to earn.
- *The extent and nature of government contributions would need to vary depending on the segment being targeted.* For example, to fund industrial start-ups, the government could provide equity contributions with leveraged upside to private investors, as mentioned in the first option. In addition, this fund of funds could have separate windows, with different investment terms, for creating funds—such as seed funds, early-stage funds, sector-specific funds (biotech, for instance), grassroots innovations, and MSMEs. For rural industry funds or pro-poor and grassroots innovations, government contributions could be in the form of low-cost loans. Expected returns for these funds would be lower than for traditional venture capital funds. In addition, the government may need to provide grants to defray staffing and due diligence costs, especially for seed stage and pro-poor innovation funds, to attract talent with investment and operational experience who can add value through intensive mentoring to rural and grassroots entrepreneurs.
- *It is critical that administration of the fund of funds be professional, free of bureaucratic burdens, and independent of political interference.* Hence, a small, independent institution could be created. Administration of the fund of funds could conceivably be a joint venture between the government and the private sector. The two main functions of the administrative body would be to select fund managers and funds to be supported, and to monitor the program once under way. The fund of funds could initially be created by consolidating some existing

government schemes administered by the Technology Development Board (TDB), Technology Information Forecasting and Assessment Council (TIFAC), and Department of Scientific and Industrial Research (DSIR)—with individual venture funds to be majority-owned and managed by the private sector.

Support for pro-poor innovation will likely require a higher grant element, because the business model for “commercial” capital to support grassroots innovations is still evolving.¹⁵ Still, principles of professional venture capital and equity investment should be institutionalized even in venture capital funds that support grassroots innovations. Government contributions could be a mix of grants and soft equity. The grants could defray staffing and due diligence costs, since attracting the right kind of management and due diligence experience for grassroots investment is even more difficult than for early-stage investing in the formal sector (as mentioned above). The soft equity could provide leveraged returns to private partners while trying to demonstrate a viable business model. Aavishkar and Acumen Fund are pioneering efforts that could shape the design of support programs for grassroots innovations. For example, Acumen Fund is targeting at least a return on capital invested, and Aavishkar is targeting a positive internal rate of return (though not as high as in traditional venture capital). “Social venture capital” may need to use a different mix of instruments than is ordinarily used—for example, a small equity investment with disproportionate voting rights in certain cases combined with conditional, sales- and royalty-based loans.

There are examples in India of venture capital funds with partial public equity contributions, being managed by private managers—such as the Gujarat Venture Finance Ltd. (GVFL) and Andhra Pradesh Industrial Development Corporation (APIDC) venture capital funds. Moreover, the collaboration between APIDC and TDB involves TDB co-investing with the APIDC fund and being entitled to “soft” returns, while APIDC investors profit from any upside potential from the investments. Lessons from these and other experiences of government support to venture capital in India over the past two decades would need to be incorporated in the design of the fund of funds.

On the demand side, it is crucial that any intervention supporting venture capital be preceded or complemented by interventions addressing the ESTD funding gap. Thus, for a venture capital instrument to work effectively, there must be a pipeline or deal flow of companies with commercial potential. A venture capital program is therefore likely to work best where support for R&D through a grants program provides critical funding at early stages to advance companies to the level that they can be supported by venture capital firms. Venture capital measures should also be coupled with reforms that improve conditions for developing a venture capital industry, including revisions to venture capital legislation and capital market reforms that increase stock market liquidity. Countries with some of the most robust venture capital industries—the United States, Israel, Canada, Australia—have active programs at all stages of the innovation life cycle, from grants through venture capital support programs. For example, Australia’s R&D Start program provides grants for commercializing innovations by MSMEs and is complemented by its Innovation Funds program, which encourages venture capital investment in innovative MSMEs (World Bank 2006b).

Improving deal flow requires multipronged reforms to improve the overall innovation climate as well as the governance, incentives, and design of India's innovation system, as discussed in previous chapters. Recommendations for increasing the quality and quantity of deal flow for the venture capital industry include the following:

- *Increasing the scale and scope of public support for business R&D and incentives for research and commercialization.* As noted in chapters 2 and 4 and in the preceding section on ESTD finance, this involves improving governance and scaling up or restructuring existing R&D grant schemes. It also requires, where relevant, introducing cooperative and horizontal R&D grant elements in these schemes. Equally important are incentives for R&D labs and universities that encourage commercialization of R&D and industry linkages. These can be achieved through legislation similar to the U.S. Bayh-Dole Act, which provided incentives for universities to invest in research (see chapter 2), and the U.S. Stevenson-Wydler Act, which encouraged the transfer of technology from labs to industry through cooperative research. Such legislation is not necessarily aimed at addressing binding constraints, but is intended more as a signaling tool to encourage R&D commercialization.
- *Fostering an entrepreneurial culture and social support.* This involves promoting social norms encouraging entrepreneurship—especially becoming more forgiving of failure and placing a high social value on commercial success. The literature on innovation and entrepreneurship worldwide emphasizes tough bankruptcy laws and procedures as key impediments to greater entry of firms (and hence start-ups) and competition. A more entrepreneurial culture could be achieved by conducting media campaigns (for example, highlighting the success of first-generation entrepreneurs in IT and manufacturing), promoting innovation and entrepreneurship awards, and creating entrepreneurship funds and technology spin-off funds (for spin-offs from corporations, R&D labs, and universities).
- *Developing complementary infrastructure and an enabling environment for innovation and entrepreneurship*—such as technology incubators, science and technology parks, university linkages, and business development services (see chapter 2).
- *Improving the investment climate and the enabling environment for business entry, operations, and exit* (see chapter 1). Needed are entrepreneur-friendly policies that encourage competition from new entrants, bankruptcy laws that permit quick recovery, and a strong intellectual property regime that creates incentives for invention and encourages research and diffusion.

Finance for Technology Absorption by Small and Medium Enterprises

Although no official data exist on the size of the finance gap facing MSMEs wishing to upgrade technology, constraints facing MSMEs in financing new investments suggest that it is large. In India, financing the adoption of innovation by MSMEs is as

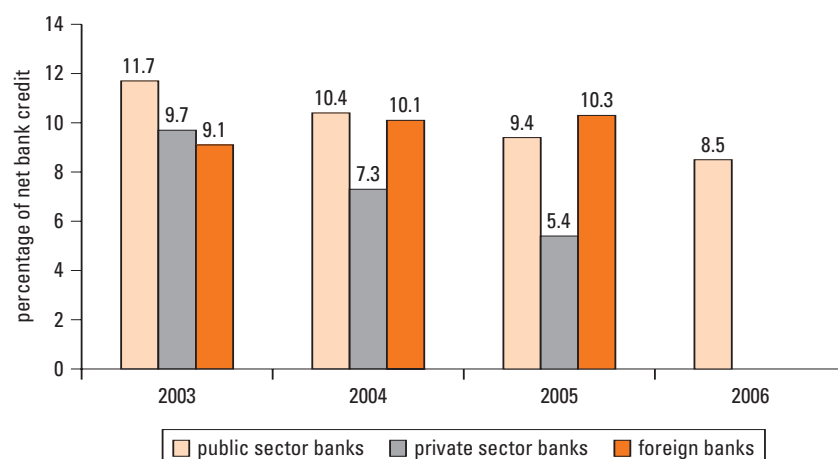
important as early-stage finance for new firms. This is especially so given this sector's importance in the overall economy and the significant differences in productivity between large firms and MSMEs across and within sectors (see previous chapters).

Access to adequate, timely finance on competitive terms has been identified by World Bank and Indian government analyses as a problem for MSMEs across the country.¹⁶ Problems in accessing credit are due to a combination of factors:

- Weaknesses in the legal framework for loan recovery, bankruptcy, and contract enforcement, together with inefficiencies in the court system—with the latter largely accounting for interstate variations in the time and cost of loan recovery and bankruptcy.
- Institutional weaknesses, such as the absence of good credit appraisal and risk management and monitoring tools in banks—increasing their transaction costs when dealing with MSMEs.
- Absence of reliable credit information on MSMEs.
- Lack of sufficient market credibility in the MSME sector. It is hard for lenders to assess risk premiums, creating differences in the perceived and real risk profiles of MSMEs and resulting in untapped lending opportunities for them.

Financing for MSEs has been insufficient, including for upgrading technology. Credit to micro and small enterprises (MSEs), including financing for upgrading technology, fell as a share of net bank credit between 2003 and 2006 (figure 7.5).¹⁷ Government efforts to spur technology financing for MSEs, such as the Credit Linked Capital Subsidy Scheme (CLCSS) for upgrading technology in small-scale industries (SSIs), have also not allocated sufficient capital to this important area. The

Figure 7.5 Credit Flows to Micro and Small Enterprises, End-March 2003–06



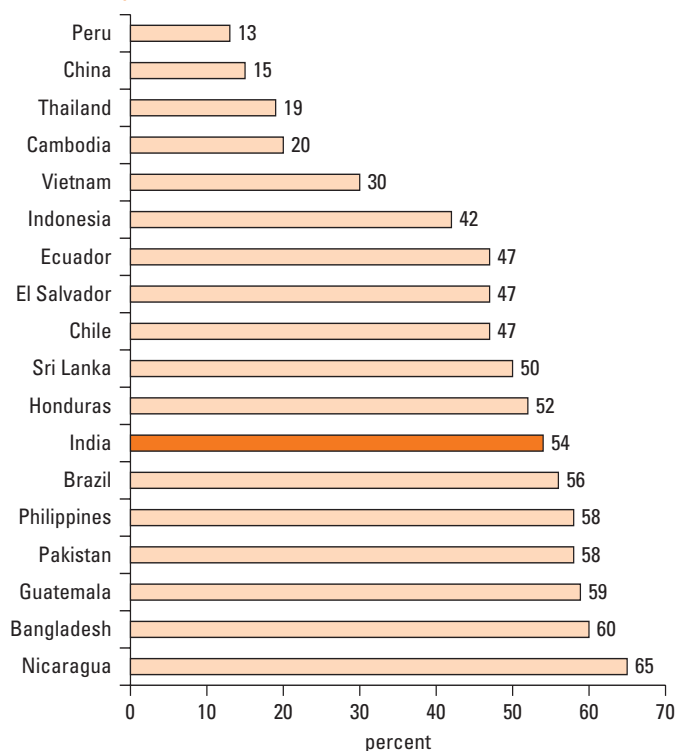
Source: Reserve Bank of India.

Note: Data for March 2006 are available only for public sector banks.

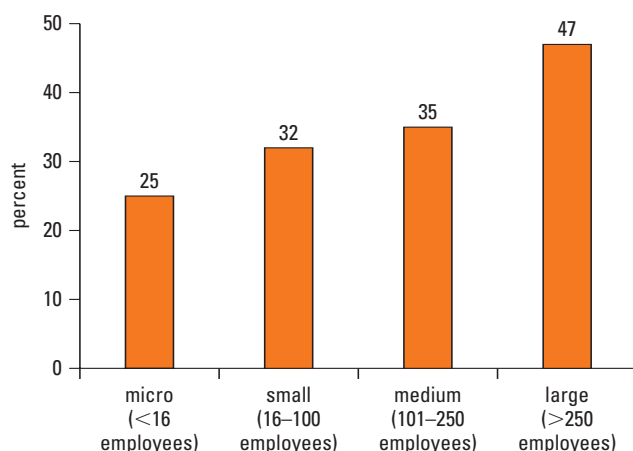
scheme, which provides a 15 percent capital subsidy to upgrade technology for SSI units in specific subsectors and products, benefited only 2,368 units in the six years ending in March 2006. Total CLCSS spending was Rs 43 crore (\$10.5 million) during this period—a small fraction of the Rs 82,275 crore (roughly \$20 billion) in credit to SSIs from public sector banks alone in the fiscal year ending in March 2006.

Enterprise surveys suggest that access to funding for absorption of innovative practices is more constrained for smaller enterprises and traditional industries. The World Bank's 2006 Enterprise Survey found that 54 percent of new enterprise investments (broadly defined as new land, buildings, machinery, and equipment)¹⁸ in India were financed using internal funding—significantly more than in most other developing countries in Asia and Latin America (figure 7.6). But the survey shows considerable variation in these results based on firm size. The smallest (micro) enterprises rely mostly on informal funding (12 percent of their new investment funding), while the largest enterprises rely primarily on commercial bank lending (47 percent of new investment funding; figure 7.7).¹⁹ Survey results also suggest that more sophisticated industries—such as pharmaceuticals, automotive components, machinery, and electronics—have greater access to bank lending to fund new investments than do more traditional industries such as rubber, metals, and garments. The

Figure 7.6 Reliance on Internal Funds for Financing New Investments, Various Countries, 2006



Source: World Bank Enterprise Surveys.

Figure 7.7 Access to Bank Finance in India, by Firm Size, 2006

Source: World Bank Enterprise Surveys.

medium-tech textiles industry, with its global markets, is an outlier, with substantial access to bank financing.

Recommendations for Improving Finance for Technology Absorption

Measures aimed at improving access to finance for MSMEs would result in better access to finance for innovative MSMEs wishing to adopt or upgrade technology. Possible measures for government action include the following:²⁰

- *Improving credit information on MSMEs* would help cut transaction costs that lead to higher interest rates for these firms. The Credit Information Bureau of India Ltd. (CIBIL) has made considerable progress in recent years and now has a large consumer database and a recently launched commercial database (95 percent of which are MSMEs). In addition, in May 2006 the government passed facilitating legislation to allow banks and financial institutions to share information on their customers with CIBIL. Now CIBIL needs to expand its data sources to include nonfinancial entities (such as utilities).
- *Addressing the issue of collateral* would reduce default risks for lenders. The government can help by improving and updating land and property records, which hamper the use of land as collateral, and by promoting the use of collateral substitutes such as lease-hold land and peer group security in the pricing of loans to small businesses.
- *Introducing legislative changes in mortgage registration* would make the process more customer friendly, and simplify the legal framework for collateral enforcement and loan recovery by introducing alternative, out-of-court methods of dispute resolution. The government could consider extending the Law on

Securitization, Reconstruction of Financial Assets, and Enforcement of Security Interest—which allows for out-of-court settlement of bad loans—to cover smaller loans.

- *Establishing a bankruptcy framework that facilitates the easy exit of small firms* would be beneficial given their relatively high mortality rate. As noted, there is a direct, positive correlation between the ease of exit for firms and the rate of new entry and level of competition in industry. India's tedious, cumbersome bankruptcy and closure regime discourages entrepreneurship. It is common for bankruptcy proceedings to take more than 2 years—and over 60 percent of liquidation cases before High Courts have been in process for more than 10 years. Not surprisingly, when looking at the share of firms that go bankrupt, India has a much lower share (0.04 percent) than do other emerging markets, such as Thailand. This could change once the envisaged amendments to the Companies Act are implemented, providing a new framework for liquidating firms outside the court process.
- *Establishing a policy and regulatory framework that fosters the development of leasing finance* would be effective for financing small, innovative businesses, which face collateral constraints and equity capital shortages. The growth of leasing finance is stifled by an inhospitable tax and accounting framework, introduced after a major leasing finance scam in 1997. As a result of government policy, India's leasing finance industry has shrunk from some 400 firms in the early 1990s to just about 10 today. To revitalize the leasing industry, efforts must be made to improve the tax and accounting framework. Clear rules are needed to help tax officers distinguish between genuine leases and garbed financial transactions. Currently, assessing officers and appellate commissioners create their own rules. Rules are also needed to allow leasing companies to deduct depreciation from lease payments for tax purposes. Finally, the service tax on rentals needs to be reduced, and state governments should revisit their policy of equating a lease with a sale—resulting in taxes on leases ranging from 4 percent to 14 percent.

Notes

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1. For discussions of these issues, see Ben-Ari and Vonortas (2005), UNCTAD Secretariat (2002), Dossani and Kenney (2003), and Bank of England (2001).
2. After the United States, India has the second-highest number of publicly listed firms. Although the shares of many of these firms are not actively traded on the stock exchanges, their liquidity has improved considerably in recent years.
3. Early-stage finance includes seed capital as well as initial finance required for start-up operations to commercialize an innovation. Although there is no clear definition, early-stage finance is usually classified by amount (say, less than \$3 million), the life of the firm (say, less than five years), or the sequence of external funding available to the firm (say, first two rounds of external finance).

4. Although there is no consensus definition of ESTD, it can be broadly defined as the stage where “the technology is reduced to industrial practice, a production process is defined from which costs can be estimated, and a market appropriate to the demonstrated performance specifications is identified and quantified” (Auerswald and Branscomb 2003: 229).
5. For a summary of these constraints, see World Bank (2006a). For a more detailed discussion, see De Ferranti and others (2003) and Baumol (2002).
6. Based on lower-case and upper-case modeling by Auerswald and Branscomb (2003).
7. These definitions vary, but seed is usually the first round of funding in the life of a firm, and series A and B are subsequent rounds. In the above-mentioned analysis, Evalueserve defines these terms based on amounts invested in the Indian context. Seed is up to \$900,000, series A is \$1 million–\$3 million, and series B is \$3.5 million–\$8.0 million.
8. It has been argued that seed and early-stage financing in India implies investments of less than \$1 million given the lower cost structure for Indian start-ups relative to their Silicon Valley counterparts.
9. APIDC’s management was privatized in the mid-1990s.
10. The Seed Fund, recently created with \$10 million from the former promoters of the Infinity Fund, is one of India’s few successful early-stage venture capital firms.
11. Evalueserve estimates venture capital and private equity investment at more than \$6 billion in 2006. But again, most of this increase is unlikely to be for seed and early-stage funding.
12. India ranks poorly on the World Bank–International Finance Corporation’s Doing Business indicators; see chapter 1.
13. For a more detailed discussion on investment climate issues facing Indian businesses, see World Bank (2002, 2004, 2005, 2006a), National Manufacturing Competitiveness Council (2006), National Investment Commission of India (2006), and *India Today* (2005).
14. Current investment guidelines for pension and insurance funds allow for investment in defined “unapproved” securities; these guidelines can be modified to include or increase the allowable limit for venture capital funds.
15. For further discussion of the evolving “social venture capital” industry, see World Economic Forum (2006).
16. Among government documents, see the Abid Hussain Committee on Small Enterprises (Ministry of Industry 1997), S. L. Kapur High Level Credit Committee on SMEs (Reserve Bank of India 1998), and S. P. Gupta Study Group on Development of Small Enterprises (Planning Commission 2001). See also World Bank (2002, 2003, 2004).
17. Until recently the Reserve Bank of India required banks to submit data only for micro and small enterprises (MSEs), which became classified as a priority sector for bank lending. With enactment of MSME legislation in May 2006, data for medium enterprises are now being collected as well.
18. Used as an approximation for innovation absorption financing, which is related to machinery and equipment.
19. For the purpose of this particular analysis, micro enterprises employ fewer than 16 people, small enterprises between 16 and 100, medium enterprises between 101 and 250, and large enterprises more than 250.
20. Although many of these recommendations apply to MSME financing in general, constraints tend to be greater for upgrading technology and innovative MSMEs, as discussed earlier. Hence, these recommendations are extremely relevant for upgrading technology for MSMEs.

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Technical Appendix

Table A.1 Formal and Informal Employment by Industrial Category, FY 2000

(percent)

Category	Formal versus informal employment within sector categories		
	Formal	Informal	Total
Agriculture	1.05	98.95	100.00
Manufacturing	18.88	80.12	100.00
Services	30.67	69.43	100.00
Overall economy	11.03	88.91	100.00
Category	Distribution of sectoral employment within formal and informal employment categories		
	Formal	Informal	Overall economy
Agriculture	5.79	67.31	60.53
Manufacturing	28.31	14.14	15.71
Services	65.90	18.54	23.77
Total	100.00	100.00	100.00

Source: World Bank 2006.

Table A.2 Innovation Outputs and Productivity: Ordinary Least Squares Estimation of Productivity Function

Dependent variable: Log value added	(1)	(2)	(3)	(4)
Log capital	0.302 (13.89)**	0.307 (14.07)**	0.267 (12.25)**	0.270 (12.33)**
Log labor	0.919 (31.28)**	0.926 (31.55)**	0.877 (29.06)**	0.879 (29.09)**
Log workforce skills	0.110 (1.71)*	0.129 (1.99)*	0.147 (2.28)*	0.149 (2.31)*
Developing an important new product line	0.258 (4.06)**		0.154 (2.45)*	
Upgrading an existing product line		0.176 (2.76)**		0.093 (1.42)
Industry	No	No	Yes	Yes
State	No	No	Yes	Yes
Missing indicator variables	Yes	Yes	Yes	Yes
Constant	7.333 (25.03)**	7.186 (24.16)**	8.321 (23.83)**	8.277 (23.52)**
Observations	1,656	1,656	1,633	1,633
R squared	0.65	0.65	0.70	0.69

Source: Analysis of India 2006 Enterprise Survey by Tan and Savchenko (2006).

Note: Absolute value of t statistics is in parentheses.

* significant at 5 percent.

** significant at 1 percent.

Table A.3 Creation versus Absorption and Productivity: Estimation of Frontier Production Function

Dependent variable: Log value added	(1)	(2)	(3)	(4)
Log capital	0.281 (.022)**	0.280 (.021)**	0.284 (.021)**	0.268 (.022)**
Log labor	0.950 (.031)**	0.948 (.030)**	0.935 (.032)**	0.871 (.031)**
Firm had positive R&D expenditures in 2004	−0.348 (.171)*		−0.326 (.188)	−0.186 (.230)
Acquired new technology		−0.783 (.197)**	−0.803 (.219)**	−0.575 (.234)*
Paid royalty or license fee to domestic or foreign firm			0.445 (.198)*	0.609 (.223)**
Any formal training				−0.643 (.255)*
Industry	Yes	Yes	Yes	Yes
State	No	No	No	Yes
Missing indicator variables	Yes	Yes	Yes	Yes
Constant	8.844 (.267)**	8.846 (.264)**	8.802 (.268)**	9.291 (.310)**
Observations	1,644	1,644	1,644	1,644
Sigma	0.7	0.7	0.7	0.7

Source: Analysis of India 2006 Enterprise Survey by Tan and Savchenko (2006).

Note: Standard error is in parentheses.

* significant at 5 percent.

** significant at 1 percent.

Table A.4 Distribution of Indian Firms by Incidence of In-Service Training*(percent)*

Indicator	Any formal training	Formal in-house training	Formal external training
Size			
Micro (<16 workers)	7.36	7.3	2.4
Small (16–100 workers)	15.7	15.0	7.2
Medium (101–250 workers)	30.7	29.2	18.2
Large (>250 workers)	43.4	40.4	25.0
Total	15.4	14.7	7.3
Industry			
Auto components	30.3	29.3	15.1
Drugs and pharmaceuticals	23.7	22.0	13.6
Machinery	19.3	20.0	9.3
Textiles products	16.3	15.1	7.2
Chemicals	15.9	15.9	8.8
Other manufacturing not elsewhere counted	15.7	15.7	5.9
Food and beverage	14.7	12.6	7.7
Electronics and electrical appliances	14.5	14.0	7.0
Garments	10.3	8.9	3.3
Plastics and rubber	9.6	8.8	3.5
Metal products	7.4	8.3	3.3
Leather products	3.2	3.2	1.6
Conduct R&D			
No	10.1	10.0	4.4
Yes	29.8	27.9	15.6
Exporter status			
No	11.7	11.5	4.8
Yes	26.7	24.8	15.5
Foreign ownership > 10 percent			
No	14.7	14.1	6.8
Yes	66.7	62.5	45.8

Source: Tan and Savchenko 2006.

Table A.5 Joint Estimation of Bivariate Probit Model for Innovation and Training Decisions

Dependent variables: innovation and training	Coefficient	z-score
Innovation equation		
Small (16–100 workers)	0.391	5.33
Medium (101–250 workers)	0.756	5.83
Large (>250 workers)	0.751	5.75
Education of general manager (category)	0.141	2.93
Average years of workforce education	0.012	2.04
Firm exports	0.488	6.36
Constant	–1.603	–6.22
Training equation		
Small (16–100 workers)	0.393	4.33
Medium (101–250 workers)	0.774	5.6
Large (>250 workers)	1.126	8.4
Foreign ownership >10 percent	0.934	3.48
Firm exports	0.262	3.03
Average years of workforce education	–0.002	–0.39
Constant	–1.456	–15.94
Number of observations	1,770	
Rho	0.289	
Wald test $\chi^2(15)$	303.36	
Log pseudo-likelihood = –1696.0296		
Prob > χ^2 = 0.0000		

Source: Tan and Savchenko 2006.

Note: The estimate of rho measures the covariance in the errors of the innovation and training equations. Both Wald and likelihood ratio tests reject the null hypothesis that rho is equal to 0, that is, they confirm that the innovation and training decisions are made jointly.

Table A.6 In-Service Training and Productivity: Estimation of Productivity Function (Ordinary Least Squares)

Dependent variable: Log value added	(1)	(2)	(3)
Log capital	0.262 (11.98)**	0.261 (11.87)**	0.257 (11.71)**
Log labor	0.872 (28.85)**	0.871 (28.77)**	0.849 (27.76)**
Log average years of workforce education	0.159 (2.47)*	0.160 (2.48)*	0.130 (2.02)*
Firm had positive R&D expenditures in 2004			0.323 (3.87)**
Acquired new technology			0.062 (0.71)
Paid royalty or license fee to domestic or foreign firm			0.043 (0.40)
Any formal training	0.282 (3.11)**		0.232 (2.53)*
Formal in-house training		0.221 (2.08)*	
Formal external training		0.158 (1.13)	
Industry	Yes	Yes	Yes
State	Yes	Yes	Yes
Missing indicator variables	Yes	Yes	Yes
Constant	8.382 (24.01)**	8.413 (23.96)**	8.526 (24.40)**
Observations	1,633	1,633	1,633
R-squared	0.7	0.7	0.7

Source: Tan and Savchenko 2006.

Note: Absolute value of t statistics is in parentheses.

* significant at 5 percent.

** significant at 1 percent.

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