Chapter 2

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, Silverthrone [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.

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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.

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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

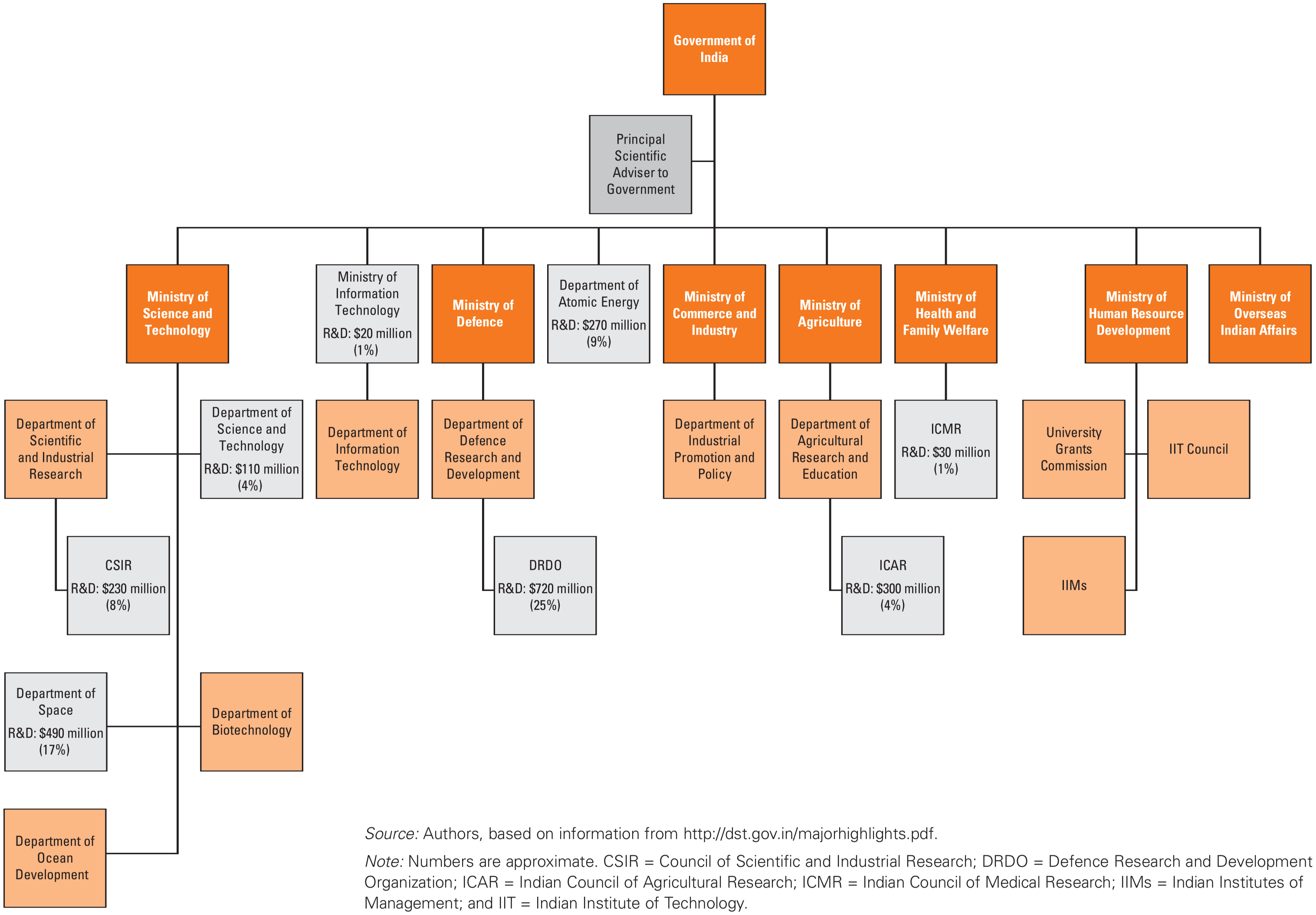
The public sector dominates domestic R&D. Figure 2.1 provides an overview of the main public institutions involved in R&D in India.[14] The public sector (central and state) accounts for 70–80 percent of India's total R&D investment, equal to 0.8 percent of GDP. The bulk of that effort is mission-oriented 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 STEPs, 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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