Biotechnology in India: Public–private partnerships

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Abstract

As the purpose of this study was a survey of public sector–private industry collaborations of the biotechnology sector in India, an organisational and functional overview of this sector was needed. Therefore, rather than studying a hypothetical biotech sector in India, the focus of this work was to study the public–private partnerships (PPP) that are occurring in India in the area of modern biotechnology. The Indian Government has been playing an important role in the development of the Biotech sector from the very beginning and there are large numbers of R&D institutions (Scientific, Medical, Industrial and Agricultural) that have been set up by the Government during the past 2–3 decades. The Indian Biotechnology industry is advancing towards new heights in alignment with the growth and progression observed globally. The past performance of the industry indicates that it has surpassed the growth rate of many other industries. This paper also highlights the favourable national policies undertaken to strengthen the Indian biotechnology industry. It is in this context that the paper shows that these collaborations are an expression of more general trends towards a changing role of the country in economic production.

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INTRODUCTION

This paper is concerned with the role of public–private sector partnerships in the development of Indian biotechnology. Its basic message is that since the role of such partnerships is becoming increasingly common in the developing countries at an early stage of economic development, there is especially a need for technology development since that will drive countries like India forward in the coming decades. The biotechnology development in India is crucial in this era because of its generic status implications for economic production in sectors as widely dispersed as agriculture, health, industry and environment. In fact, the growth in biotechnology research and development (R&D) has been rapid in the recent years but most of it has taken place in the private sector.[1]

The Indian biotechnology sector crossed the US $2bn mark during 2006–2007. Although this accounts for only a little more than 1 per cent share of the global biotech market, the encouraging sign is that the sector

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is riding on a healthy growth rate of over 35 per cent annually over the last five years. The prognosis is good and consensus among industry leaders and policy makers is that, with proper fiscal and policy initiatives, the sector could easily scale the US $25bn figure by 2015. There are today about 300 biotech companies in India, with the top ten accounting for 50 per cent of the revenue generated, and R&D investment of the top five exceeding US $300m. Geographically, the biotech companies have developed in three major bio-clusters across the country. The largest in terms of revenue generated is the western India, followed by the south and the northern area. Exports contributed to 42.17 per cent of the total business, with bio-pharma products currently contributing to 73.15 per cent of the exports. The key opportunity segments are: bio-pharmaceutical (vaccines, therapeutics, diagnostics), bio-agri (transgenics, biofertilisers, biopesticides), bio-industry, bio-informatics and bio-services (R&D, clinical trials and manufacturing on contract). The bio-agri segment registered the highest growth rate during the year at 154 per cent , followed by bio-services (54.6 per cent), bio-industry (34.55 per cent), bio-pharma (30 per cent) and bio-informatics (25 per cent).[2]

According to the traditional view, there is a natural division of labour between the public sector, which is responsible for the production of public goods, and the private sector, which does the same for private goods. The former commodities that cannot be given a market price are therefore best funded out of collective tax revenues, whereas the latter are the commodities that can be allocated using prices. The resultant need for increased taxation to pay for these public commodities has proved both politically unpopular and unmanageable, where the revenues cannot be raised. The result has often been a decline in the level and quality of such 'public' goods and services. The research and development in biotechnology needs certain rules to be clearly fixed in order to reach its optimal level in a country like India. The first rule that needs to be fixed for the private as well as the public research to have a reasonable incentive to invest in research leading to economic application is the rule of intellectual property protection.

Strategies for technology and competency development or acquisition are the central factor determining the success of these ventures. Indian policy of research support and human resource development through the funding of several public research and teaching institutions is of course a critical factor determining the technology availability. The interactions between those public institutions and the Indian companies were the object of this specific analysis. It appears that institutions and companies are learning to work together and the effects of this collaboration can help the companies at various stages of their development. It also appears that companies often adopt alternative solutions to collaboration with Indian institutes such as collaborations with foreign companies or institutions. The personal networks built by the managers of these Indian firms – many of them have had an international academic or corporate carrier – are the main determinants of those international connections.[3]

The public–private environment can greatly influence the growth of the biotechnology sector in India to understand the mechanisms of interaction between the public research institutions and the companies with biotech activities. The public–private involvement plays a critical role in the development of the biotechnology sector. The areas include human resource development, public research and infrastructure development. The main government agencies are responsible for financing and supporting research in biotechnology. The share of each budget actually dedicated to biotechnology research funding is not available.

SCIENTIFIC SUPPORT

Government agencies

The Central Government is responsible for major policy relating to higher education in India. Figure 1 shows the administrative organisational set-up of the government agencies involved in the funding of public research. The National Biotechnology Board (NBTB) under the Ministry of Science and Technology, as an apex coordinating body to identify priorities, oversee and plan for required manpower, integrated industrial development and large-scale use of biotechnology products and processes. Several government agencies like Department of Science and Technology (DST), Department of Scientific and Industrial Research (DSIR), Council for Scientific and Industrial Research (CSIR), Indian Council for Agricultural Research (ICAR), Indian Council for Medical Research (ICMR), Department of Atomic Energy (DAE) and University Grant Commission (UGC) are dedicated to biotechnology development in India. The UGC is responsible for the coordination, determination and maintenance of standards and for the release of grants. The Department of Biotechnology (DBT) is promoting the development of specialised degrees, such as MSc in Biotechnology or Bio-informatics in several institutions. The State Governments are responsible for the establishment of State Universities and colleges, and provide plan grants for their development and non-plan grants for their maintenance.[4–6]

Research institutes

The research institutions supervised by DBT include: The National Institute of Immunology (NII), New Delhi; National Centre for Cell Science (NCCS), Pune; National Brain Research Centre (NBRC); National Centre for Plant Genome Research (NCPGR), New Delhi; and Centre for DNA Fingerprinting and Diagnostics (CDFD), Hyderabad.

The CSIR laboratories involved in major biotechnology-related research include: Centre for Biochemical Technology (CBT), Delhi; Centre for Cellular and Molecular Biology (CCMB), Hyderabad; Indian Institute of Chemical Technology (IICT), Hyderabad; Central Drug Research Institute (CDRI), Lucknow; Institute of Microbial Technology (IMT), Chandigarh; Indian Institute of Chemical Biology (IICB), Calcutta and Central Food Technological Research Institute (CFTRI), Mysore.[4–6]

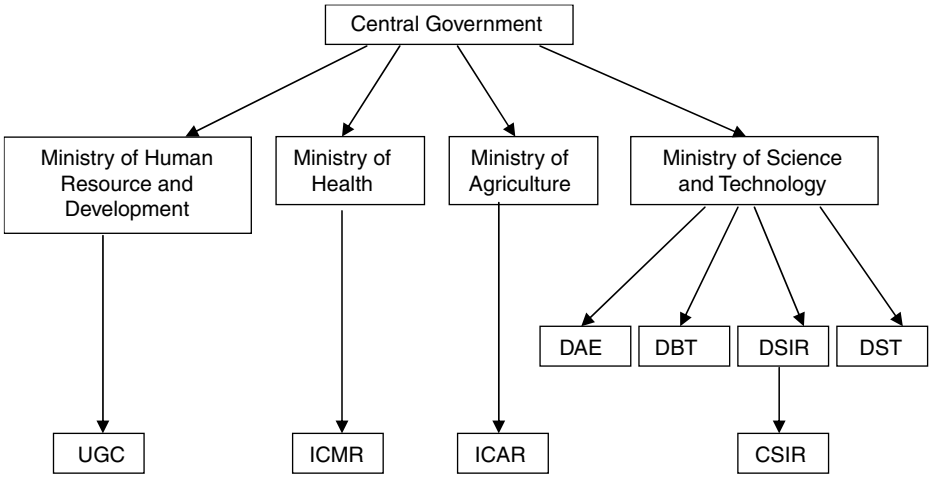

Figure 1: Administrative organisation of the government agencies involved in the funding of public research

The Tata Institute of Fundamental Research (TFIR) and National Centre for Biological Science (NCBS) in Bangalore are funded by DAE, which carries out basic research in biological sciences. The ICMR has established centres for developing molecular medicine at Sanjay Gandhi Post Graduate Institute of Medical Sciences (SGPGIMS) New Delhi; All India Institute of Medical Sciences (AIIMS), Lucknow; Post Graduate Institute of Medical Education and Research (PGIMER), Chandigarh; and Jawaharlal Nehru University (JNU), New Delhi. The ICAR has established a National Research Centre on Plant Biotechnology (NRCPB) at the Indian Agricultural Research Institute (IARI), New Delhi.

Some other institutes based in India are not directly under the supervision of any Indian Public Agency. For example, the International Centre for Genetic Engineering and Biotechnology (ICGEB) is in fact an international organisation whose statutes were signed by 26 countries under the form of an international treaty in 1994. The Institution is structured in two components located in Trieste, Italy, and in New Delhi, India. The ICGEB is an autonomous, international, intergovernmental organisation supported by the United Nations Industrial Development Organization (UNIDO). Some Indian institutes such as the Bose Institute (Independent research institute of outstanding scientific level located in Kolkata) also work without any direct support from any Indian public agency. The revenues from these centres come from external project funding.[4–6]

NATIONAL POLICIES

Government support has given a significant boost to the fledgling Indian biotech sector. In recent times, the Indian government has formulated a few new policies and made amendments to the existing ones, which support the biotech segment. Many of these policies, like the Stem Cell Research guidelines, Pharma Policy, Seed Policy, Special Economic Zone (SEZ) Act and Foreign Trade Policy, are essentially roadmaps for the respective sectors and aim at unshackling of controls, creating an atmosphere of trust and transparency, simplifying procedures, along with offering attractive incentives where possible. Put together, they create a vibrant atmosphere for the holistic growth of the life sciences/ biotechnology sector.[7,8]

Recently, a draft policy on National Biotechnology Development Strategy has been made public to invite wide comments. A quick reading indicates that it is clearly an industry-friendly policy with most of the major demands of the industry finding prominent mention in it. It aims to make the processes easier, quicker and friendly for the common man. The policy will provide adequate support to basic, translational and clinical research. Up to 30 per cent of the biotechnology research budget will be spent through public–private partnerships (PPP). A major aim of the Strategy is the development of human resources. The government plans to set up centres of excellence in the fields of marine biotechnology, animal biotechnology, herbal medicine, molecular medicine and bio-informatics. There will be no restriction on the quantum foreign direct investment (FDI) in biotech companies and there may not be a need for FIBP (Foreign Investment Promotion Board) approval for equity investment in biotech companies. The Indian Foreign Trade Policy is essentially a roadmap for the development of India's foreign trade. Identifying and nurturing different special focus areas to facilitate development of India as a global hub for manufacturing, trading and services is one of the key strategies highlighted in the Policy to increase the country's foreign trade. With an idea to boost exports, rope in investments, development of infrastructure and generate employment, the government introduced the concept of SEZs in the year 2000. The SEZ Act came into force in India on 10th February, 2006.[7,8]

The Indian rules and regulations as well as procedures for handling of the genetically modified organisms (GMOs) and rDNA products have been formulated under the Environment Protection Act (EPA) 1986.[8] The rules enforced since 1993 cover manufacture, use/import/export and storage of hazardous micro-organisms, genetically engineered organisms or cells. These guidelines have been revised to match with the newer aspects of technology. In order to provide a special thrust to genetically engineered drugs, the Mashelkar committee report [9] on recombinant pharma products streamlines the regulatory process for the approval of all recombinant DNA products. The recommendations of the report came into effect from 1st April, 2006. According to the Task Force Report, Living Modified Organisms (LMOs) are defined as only those organisms modified by rDNA techniques through human interventions where the end product is a living modified organism. The second group of public action is gathered under the name of regulation, that is, the definition of the legal environment, for example concerning the protection of the intellectual property, but also the appointment of public agency in charge of the different control procedures, as well as the definition of the different fiscal, trade and investment norms.

Regulatory policies in general are compliance friendly. However, the major criticism in this respect is that at present there are too many agencies involved in giving regulatory clearances. To address the concern of both the public and the private sector, efforts are under way to establish a single-window regulatory mechanism or to put in place a structure that could promote speedy commercialisation of recombinant products and processes. Overall, the system is relatively open and transparent yet precarious in its approach. In a nutshell, there is enough expertise in technology and risk assessment of genetically modified (GM) plants and therapeutics in terms of safety to the environment as well as human and animal health. Keeping up with the recent trends/public perceptions on GM foods, appropriate measures and mechanisms are being evolved to label the same. GM detection and analytical food safety laboratories have been established to facilitate the generation of scientific data. Similarly, containment facilities at the biosafety levels three and four are also available for both research and *in vivo* evaluations. The main objectives of the National Seed Policy are the creation of an appropriate climate for the seed industry to utilise available and prospective opportunities, safeguarding the interests of the Indian farmers and the conservation of the agro-biodiversity. In the context of application of modern technologies to agriculture, it aims at providing a conducive atmosphere for application of frontier sciences in varietal development and enhanced investments in R&D. The Pharmaceutical Policy has laid emphasis on indigenous research and development in the pharma sector. To provide encouragement, the policy has led to the establishment of the Pharmaceutical Research and Development Support Fund (PRDSF) under DST. The DST has also constituted a Drug Development Promotion Board (DDPB) on the lines of the Technology Development Board to administer the utilisation of the PRDSF.[10]

With the third amendment to the Patents Act 1970 in 2005, India entered the product-patent regime and became TRIPS-compliant. The salient feature of the amended Act is that it provides for product patents unless otherwise excluded. Interpreted in the context of life sciences/biotechnology, plants, animals and seeds, including essential biological processes used for propagating plants and animals, are not patentable. Microorganisms, however, are patentable. Synthetic genes (as distinct from naturally occurring gene segments) and genetic interventions would now be the subject matter of patentability. Genetic interventions will include single nucleotide polymorphism (SNP), vectors,

recombinant products such as vaccines, enzymes, hormones, etc.

However, much still needs to be done if India is to assume its rightful role in the global bioeconomy. The draft National Biotechnology Development Strategy (prepared by DBT after nearly two years of consultations with all stakeholders) has identified a number of issues that require urgent attention in the quest to create a favourable and enabling environment for enterprise creation and private sector development. Some of the issues that need to be urgently translated into policies and actions are: (a) creating a pool of technologically skilled human resource in adequate numbers; (b) capacity building in areas such as IPR management, technology transfer and clinical trials, etc; (c) creating institutions with a new ethos for seamless conversion of knowledge into products and processes; (d) greater support to industry, especially small and medium sector enterprises; and (e) putting in place a world-class regulatory system and ensuring adequate training for regulatory personnel. Recently, the Global Institute of Intellectual Property (GIIP), co-headquartered in New Delhi and San Jose, USA, announced the launch of a Post Graduate Diploma Program in Patents and Intellectual Property (IP) services. The GIIP programme is claimed to be the first of its kind in the world to train professionals for the rapidly growing global patent and IP services business , in collaboration with the Indian Institute of Technology (IIT) Delhi.[11]

BIOTECH PARKS AND INCUBATORS

The idea of biotechnology parks is directly derived from the successful experience of the information technology parks in this country. With the opening up of the country's economy and liberalisation, Indian industry has taken many steps to reorient itself, and to move towards knowledge-based economy. Further, in the light of the agreement on Trade Related Intellectual Property Rights (TRIPS) of the World Trade Organization (WTO), entrepreneurs have started thinking more and more about indigenous technologies, their development, perfection and absorption by the industry. Through concerted support to R&D by government, many research leads are now available. The contribution of the private sector in the R&D efforts has also improved considerably. The commercialisation of new technologies needs to be accelerated to meet the future challenges in order to realise the full potential of biotechnology.[12]

The DBT has initiated a new programme for establishing biotech parks and incubators to facilitate up-scaling, pilot-level production and finally commercialisation of indigenous biotech products. These parks offer privileged conditions to the companies implanted within their location. Those advantages can take the form of good infrastructures for water and electrical supply, air treatment, etc as well as special regulatory schemes. From the point of view of the public power, the concentration of companies of a same type in a limited area allows to maximise the local externalities and to experiment more easily specific regulatory schemes. Therefore, more than a certain kind of public action, the settlement of a biotechnology park is a way to enhance the efficiency of focused policies by gathering the companies of the targeted sector in a restricted geographical area. Several projects of biotech parks have been launched by public authorities. At the central level, the creation of biotechnology parks has been identified as the thrust area of pro-industry intervention for the DBT, whose action had been previously mainly directed towards education and research.[13]

At the State level, the States of Andhra Pradesh, Karnataka, Maharashtra and Tamil Nadu, which have issued biotechnology policy papers, have included the creation of biotechnology parks in their agenda.

Public sector undertaking/ international collaboration

Bharat Immunologicals and Biologicals Corporation Limited (BIBCOL) was incorporated in March 1989 as a Public Sector company at Bulandshahar, UP, to manufacture Oral Polio Vaccine (OPV) and other immunobiologicals. It is a highly modern manufacturing facility that follows Good Manufacturing Practice (GMP) as specified by WHO and US Federal Standards.[14]

The company has been formulating OPV from imported bulk since January 1996 and about 700 million doses have been supplied to the National Immunization Programme. This includes OPV supplied through UNICEF. The company is making profit in its current operations for the last few years. As a result of this, it has been possible to achieve a one-time settlement with the financial institutions and banks. The company's net worth has become positive and, therefore, it has been discharged from the purview of the Sick Industrial Companies (Special Provision) Act, 1985 in August 2002. The process of obtaining cabinet approval for financial restructuring of the company to give effect to one-time settlement with Banks and Financial Institutions is at an advanced stage.

The Indian Vaccines Corporation Limited (IVCOL) was incorporated as a joint venture company in March 1989 to undertake research and development and manufacture of viral vaccines. Owing to problems arising out of change in product mix and technology transfer, the company is on hold since February 1992.

The decision of the Cabinet to restructure IVCOL and to utilise the assets created has been substantially implemented. The National Brain Research Centre has been established on the premises. The pattern of shareholding in the Indian Petrochemicals Corporation Limited (IPCL), one of the promoters of IVCOL, has changed with the acquisition of controlling shares of IPCL by Reliance Industries Limited (RIL). The new management of IPCL has submitted a proposal for acquisition of controlling shares of IVCOL and revival of the company. The proposal has been considered and is being submitted to the competent authority for its decision shortly. It is expected that within the next few months, IVCOL will be restructured and revived.[14]

INDUSTRY PROMOTION

The main national biotechnology strategy is to create such tools and technologies that address the problems of the largest section of the society, provide products and services at affordable prices and make India globally competitive in the emerging bio-economy. Developing a strong biotechnology industry and technology diffusion capacity is critical to fulfil this vision. The advancement of biotech as a successful industry confronts many challenges related to research and development, creation of investment capital, technology transfer and technology absorption, patentability and intellectual property, affordability in pricing, regulatory issues and public confidence and tailor-made human resource related to all these aspects. Central to societal impact are two key factors: affordability and accessibility to the products of biotechnology. Policies that foster a balance between sustaining innovation and facilitating technology diffusion need to be put in place.[15]

The key mechanisms shall be ensuring participation of small and medium enterprises (SME) while developing technology strategies nationally, increased public contribution for early stage, high-risk research for SMEs, increase the access of SME scientists to public institute facilities and vice versa, new models of partnership with large industry to pursue path-breaking technology initiatives and building greater flexibility in public institutes to be able to work with industry. Specific initiatives are:

- Major expansion of the Small Business Innovation Research Initiative (SBIRI):

SBIRI scheme widely acclaimed in the country by SMEs. A Special-Purpose Vehicle (SPV) may be created for managing this scheme professionally.
- Biotechnology Industry Research Assistance Programme (BIRAP) may be put in place for monitoring, supporting and nurturing R&D in small and medium biotechnology companies.
- Public-funded successful R&D Enabling Public Institutions to work with Industry: institutes may be allowed and supported to establish not-for-profit companies to facilitate collaborative work with industry. In these facilities, industry scientists can pursue innovative projects for defined periods on user charge basis providing access to centralised equipments and scientific consultation.
- Public Partnership with Large Industries: Public partnership with large-scale companies may be encouraged and supported in areas that are vital to the national development from a scientific, economic or social perspective and focused on technology and product development. The company would then have preferential access to the intellectual property generated in such jointly funded projects.

Biotechnology industry in India has been growing at an average annual rate of 40 per cent and the biotechnology business segment has the potential of generating revenues to the tune of US $10bn and creating one million jobs by 2010 through bio-products and services. The Indian Biotech sector is acquiring global visibility and is being seen as a major investment opportunity. These resources need to be effectively marshalled, championed and synergised to create a productive enterprise.[15]

Industry funding

Private sector investment has also been picking up since 1997 and became particularly visible after the announcement of the draft human genome sequence in the year 2000. There are no authentic statistics on the investment in the private sectors. This is because the definition of biotechnology and its indicators vary for different estimations. An Indian directory prepared by Biotechnology Consortium India Ltd. (BCIL) includes biotechnology activities of about 176 companies in the private sector whose products range from those in agriculture, environment and healthcare. On the other hand, estimates have also been made that about 800 companies are operating in various sectors of biotechnology, based on the definition that biotechnology includes basic industry such as food processing and highly sophisticated recombinant products. Employing the same definition, one estimate states that 10 per cent (80) of these companies are operating in modern biotechnology sectors while according to another conservative estimate there are only 20 companies engaged in sophisticated biotechnology business. Similarly, it is also estimated that the industry employs 10–20,000 people and generates roughly revenue of US$500m annually. The Indian share of the biotechnology market was estimated at US$800m in 1999 and has risen approximately to US$2.5bn this year.

Notwithstanding these figures by various estimations, it can be concluded that India's burgeoning biotechnology sector is an oasis of rich picking for investors as the government leads the drive to develop the industry. Building a biotechnology industry is a part of the knowledge economy strategy of the government. A growing number of high-quality Indian biotechnology investment opportunities exist for both early- and late-stage investors. Some of the major investors including Connect Capital, ING Barings, Dresdner Kleinwort Benson, London and Warburg Pincus are evaluating Indian biotechnology investment opportunities. And that is not all; a London Stock Exchange-listed biotechnology company (with a market capital of US $125m) is keen to ally with an

Table 1: Public–private partnerships of Indian biotechnology sector*

Private company	Public partners
Avestha Gengraine Technologies Pvt. Ltd., Bangalore	NCBS University of Agricultural Sciences ICRISAT Imperial College, London, UK
Bangalore Genei Pvt. Ltd., Bangalore	CCMB IBA – ICAR
Bharat Biotech, Hyderabad	DBT – AIIMS ICGEB – AIIMS CBT
Biological E., Hyderabad	IISc International Centre for Diarrhoeal Disease Research (ICDDR), Bangladesh. National Institute of Health (NIH), USA. Nederlands Vaccine Institute (NVI), Netherlands
Genotypic Technology, Bangalore	CBT IISc Madhurai Kamraj University
Monsanto, Bangalore	IISc TERI Kenyan Agricultural Research Institute
Nicholas Piramal India Ltd., Mumbai Panacea Biotec, New Delhi	CBT NII Jawaharlal Nehru University, New Delhi Biotechnology Consortium of India National Institute of Health, USA
Rallis India, Mumbai	ICGEB IISc University of Madurai World Health Organization (WHO)
Serum Institute of India Ltd., Pune	World Health Organization, Switzerland Health Protection Agency, UK Program for Appropriate Technology in Health (PATH), USA
Shantha Biotechnics Ltd., Hyderabad	CCMB IISc Bhabha Atomic Research Center NII IICB JNU ICGEB NCCS Anna University Osmania University BARC Tata Memorial Hospital International Vaccine Institute, Korea
Shapoorji Pallonji Biotech Park Pvt. Ltd., Hyderabad	CCMB University of Hyderabad Research Triangle Park, USA Technologie Park Heidelberg, West Germany
Strand Genomics Ltd., Bangalore	IISc CSIR Project Team CDFD
Wockhardt Ltd., Mumbai	ICGEB

*Data collected from the companies' websites and Google search.

Indian biotechnology firm, possibly via a merger. It has also been predicted recently by both Indian and US Business leaders that US stock market listings by Indian technology companies could explode to 100 or more new issues within the next five years.

SMEs are the most dynamic segment of the Indian economy, and their growth generates ripple effects in urban and rural areas – creating jobs, fuelling small-scale businesses through the supply chain and expanding prosperity. But the equity marketplace in India virtually ignored SMEs until recently, when prescient backing by the Small Enterprise Assistance Fund (SEAF) and the United States Agency for International Development (USAID) in 2004 demonstrated their bullish potential.

USAID and SEAF joined forces to mobilise investments in small, fast-growing businesses at a time when SMEs had a 'high-risk' reputation. They were untapped by Indian banks and financial institutions. USAID's support of $5m including substantial equity participation in the Fund, combined with SEAF's international experience building businesses in emerging economies, sparked the interest of financiers to eventually generate a $160m 'India Growth Fund' – a pool that well exceeded expectations.[15]

Metahelix, an agricultural biotech company, is developing home-grown Indian seed varieties and new technologies for farmers. It is close to launching the first Indian Bt cotton seed on the market, with a price tag that is expected to be 40 per cent less than what is available on the market today. It is looking to export its products to underserved agricultural markets in Vietnam and Bangladesh.

ACADEMIA–INDUSTRY COLLABORATIONS

As companies face the pressure from increased competition, shortening product lifecycles and growing product complexities, many are finding that they need to change the way they develop new technologies, products and services. As companies realise they can no longer afford to rely solely on their own R&D and need to acquire ideas from others, there has been a trend in many sectors away from a mostly closed to a more open model of innovation. Considering the smaller size of the Indian biotech industry, the growth can be effectively managed by pooling resources (research facilities, technological competence, manpower requirements, risk-taking ability, etc) and passing the knowledge between firms more quickly and effectively to catch up with the industry in the west. The latest technologies in the information and communication field could be used to achieve the same. Also, the knowledge spillover can be effectively used for the industry by managing the clusters effectively. Alliances have become very popular on account of the desire by most companies to achieve higher returns in their R&D as well as operations. Innovations have become the key to survival and growth in this highly growing technological era. Owing to the limitations of knowledge resources to generate greater innovative capabilities, companies have taken the route of collaboration. Alliances provide access to complementary skills and capabilities and also bring economies of scale and scope.

India already has strong assets for the development of a competitive and innovative industry with a countrywide network of research institutions. These institutions have a recognised academic level to transfer their knowledge to the industry, either by institutional collaboration, or by the direct migration of scientists from the public to the private sector.

Table 1 shows the interactions between some of the public research institutions and private companies in the field of modern biotechnology. The companies listed here have more than one academic partner, indicating the fact that companies and institutions are still learning how to work together.

Several factors have contributed to the current upbeat feeling about India's biotech

sector. Among the strengths we can count are our wealth of biodiversity: a sizeable English-speaking scientific workforce, a robust IT base, a reasonably good infrastructure network, a well-positioned pharma industry, a strong MNC presence and a large, diverse, therapy-naïve population with a varying gene pool. The Government, both at the centre and in the states, has provided several fiscal and other incentives to the sector in terms of tax holidays, capital subsidies, creation of biotech parks, special economic zones, incubators, etc. Private firms can approach DST's Technology Development Board (http://www.tdbindia.org/), which offers soft loans with minimum interest, and DBT's Small Business Innovation Research Initiative (http://dbtindia.nic.in/SBIRI/SIBRI_main-F.html), which funds early/late-stage research, that was set up to boost PPP. India's IPR regime has become fully TRIPS compliant to promote innovation.[1] A single-window biotech regulatory authority is on the anvil to ensure a science-based efficient process. Indian biotech companies have not only been resourceful in leveraging various financing opportunities from both domestic and international sources but also proactive in establishing and maintaining collaborations and partnerships in India and abroad. They have also aimed to become competitive by patenting products and technologies on a global basis.

CSIR has designed a unique PPP called 'New Millennium Indian Technology Leadership Initiative' (NMITLI).[15] It is the biggest PPP in post independence India involving 65 private sector companies and 160 institutions and universities. It has a high emphasis on drugs and pharma R&D partnerships. Some of the NMITLI projects funded by CSIR initiative are shown in Table 2.

At present, there are 37 ongoing projects, which cover diverse areas ranging from liquid crystals to decentralised power packs; mesoscale modelling to nano-material catalysts; microbiological conversions to biotech molecules; fictionalisation of alkane to advanced nano-materials and composites; defunctionalisation of carbohydrates to biodegradable plastics; novel office computing platforms to low-cost horizontal axis wind turbines; and new targets and markers for cancer to advanced drug-delivery systems.

India's National Association of Software and Service Companies (NASSCOM), the not-for-profit trade body of the IT software and services industry, has mooted an India Innovation Fund to provide angel stage funding to start-ups to drive innovation in emerging technologies in the areas of IT and biotechnology. The fund will be set up through a PPP, where the government role will be limited. The investment decisions will be taken up by professional fund managers. The fund will allow private investors to acquire stakes in the professionally managed PPP fund.[15,16]

Benefits for the public for partnerships with the private sector

The private sector has a number of comparative advantages and the public sector can benefit from the following:

- The private sector has huge networks of companies ranging from small-intensive to large multinational companies.
- It has large R&D funding available to carry out high return short-term and long-term biotechnology projects.
- It has a good understanding of market knowledge and distribution systems.
- It has large talent pool of scientific research resources and demand-driven efficient R&D facilities.

To maximise these benefits, developing countries like India should depart from the tradition of viewing the private sector as being a profit-propelled establishment. The PPP should be viewed as a mutual beneficial association.

Table 2: NMITLI projects funded by CSIR initiative[16]

Project	Public	Private
Development of novel fungicides	IICT, Hyderabad, IMT, Chandigarh and MS University, Baroda	Rallies India Ltd., Bangalore
A catalytic process for the economical production of acetic acid from ethane	IICT, Hyderabad	Indian Petrochemicals Corporation Ltd, Baroda
Latent M. tuberculosis: New targets, drug-delivery systems and bioenhancers and therapeutics	Bose Institute, Kolkata, CDRI, Lucknow, CDFD, Hyderabad, IICT, Hyderabad, IISc, Bangalore, Tuberculosis Research Centre, Chennai	Lupin Laboratories Ltd, Mumbai Astrazeneca India, Bangalore
Biodegradable polymers from agricultural wastes: cellulose esters based on bagasse-derived cellulose	Central Pulp and Paper Research Institute, Saharanpur	EIDParry Ltd., Chennai, Godawari Sugar Mills/Somaiya Organic Chemicals Group, Mumbai, Reliance Industries, Mumbai
Biotechnology of leather: Towards cleaner processing	Central Leather Research Institute, Chennai	SPIC Science Foundation, Chennai
Value-added polymeric materials from renewable resources: lactic acid and lactic acid-based polymers	CFTRI, Mysore, IICT, Hyderabad, IIT, Bombay	Godavari Sugars Pvt. Ltd. (Somaiya Group of Industries), Mumbai Prathishta Biotech Industries Pvt. Ltd, Hyderabad and Reliance Industries Ltd, Mumbai
Biotechnological approaches for improvement of plant species with special reference to pulp and paper	Central Institute for Medicinal and Aromatic Plants, Lucknow, Forest Research Institute, Dehra Dun, Lucknow University, Lucknow, Osmania University, Hyderabad	ITC Ltd., Kolkata, Ballarpur Industries Ltd., Gurgaon, and J.K. Paper Ltd., New Delhi
Synthesis of selective β3-adrenegic receptor design, synthesis and testing of new chemical agonists as a novel therapy for obesity	Central Drug Research Institute, Lucknow, and Indian Institute of Chemical Biology, Kolkata	Glenmark Pharmaceuticals & Research Centre, Mumbai

Factors preventing PPP

Despite the efforts of Indian government in promoting the public–private tie-up, there are various factors that hinder the growth of PPP at the regional, national and global levels. First, there is a lack of information and awareness on possibilities of this kind of collaboration on the part of the public sector. Secondly, the public is often suspicious of the private sector and perceives it as an entry only interested in maximising profits. This forecloses opportunities for collaboration in mutually beneficial factors. Thirdly, there is mismatch in technological and financial resource capability between the public and private sectors. This makes finding the common ground for research on an equal basis difficult. Further, the general infrastructure (skilled human resources, research equipment and facilities) in the public sector is in some cases not supportive of meaningful partnerships with the private sector.

CONCLUSION

The main aim of this monograph has been to show in some detail that PPP are an essential component in the establishment of a biotechnology capacity in developing countries like India and especially where the needs and opportunities are demanding. The PPP are not a new phenomenon but have actually played a fundamental role in the advancement of biotechnology in developed countries and many parts of the developing world. The paper has also shown a range of interesting examples of institutional–industrial collaborations that have been increasing in India. Conversely, the state-of-the-art biotechnology knowledge and facilities are

increasingly found to be in the private sector. It is therefore clear that the Indian policy makers must now place heavy priority on building appropriate links with the private sector both to revitalise the existing capacity, and more importantly, to build enough new capacity in biotechnology to ensure its effective deployment in the major areas of food, health and environmental stability. It is therefore concluded that the public–private symbiotic associations yield many mutual benefits.

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